DOCUMENT RESUME

ED 199 036 SE 033 623

TITLE	Total Energy Management: A Practical Handbook on Energy Conservation and Management. For Use of Owners and Managers of Office Buildings and Small Retail Stores. 2nd Edition.
INSTITUTION	National Electrical Contractors Association, Washington, D.C.; National Electrical Manufacturers Association, Washington, D.C.
SPONS AGENCY	Federal Energy Administration, Washington, D.C.
PUB DATE	79
NOTE	96p.; Not available in hard copy due to copyright restrictions. Contains occasional marginal legibility.
AVAILABLE FROM	National Electrical Contractors Association, 7315 Wisconsin Ave., Washington, DC 20014 ($2.50 for first two copies, 3-500 copies $2.00 each, over 500 copies $1.75 each).
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	Building Operation; *Building Systems; *Business Administration; *Cost Effectiveness; Energy; *Energy Conservation; Heating; Money Management; Utilities
IDENTIFIERS	Energy Consumption; *Office Buildings; Retail Stores

ABSTRACT

Described in this guide for owners and managers of office buildings and small retail stores, is a program entitled Total Energy Management (TEM). The TEM program approach rests on the premise that buildings should be examined in terms of total energy consumption, rather than prescribing energy budgets for a building's separate systems. The program's ultimate objective is to bring all systems to peak efficiency and maintain that efficiency through continuing management efforts. Presented are chapters on building analysis, energy audit procedures, guidelines for energy conservation, financial evaluation, and plan implementation. Also included are TEM worksheets and references on energy management. (Author/WB)

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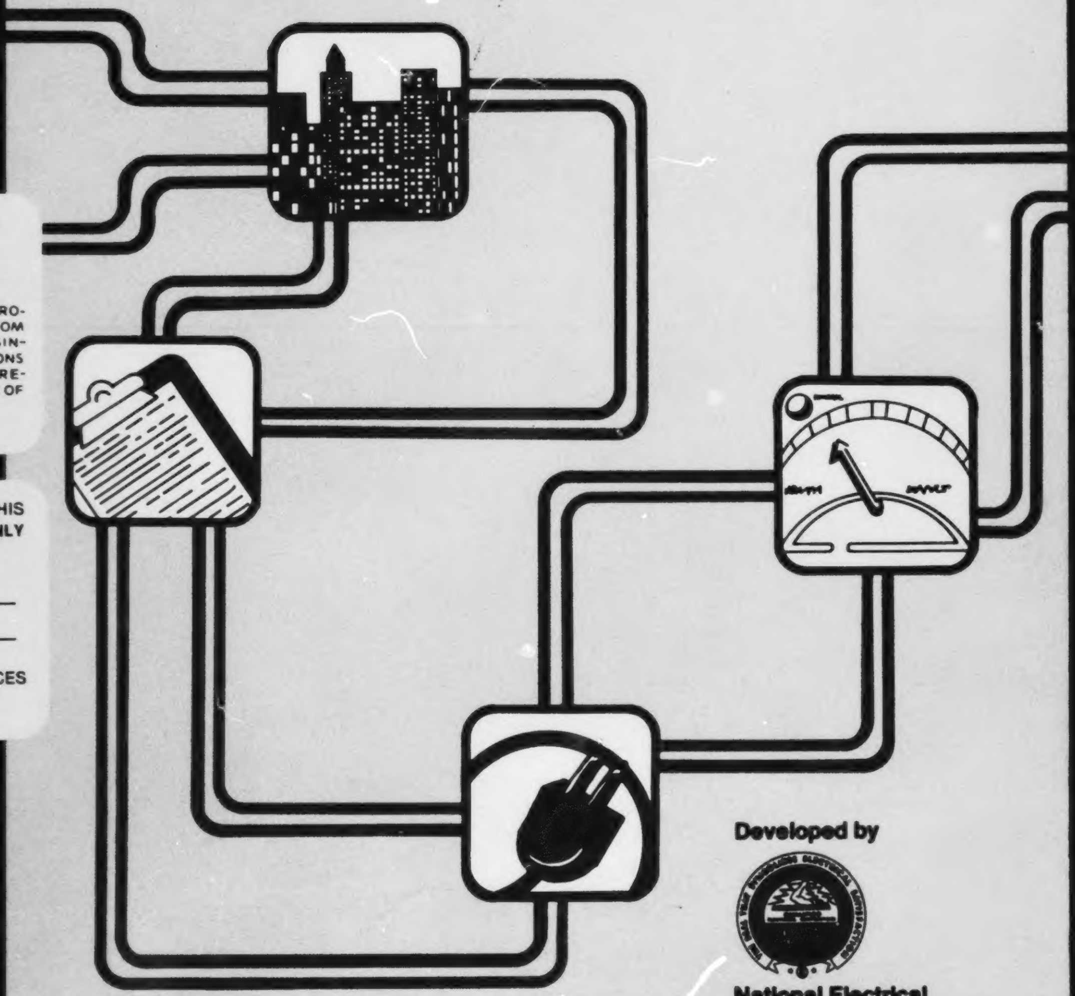
TOTAL ENERGY MANAGEMENT

A Practical Handbook on Energy Conservation and Management



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Developed by

National Electrical
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National Electrical
Manufacturers Association

2nd Edition

SE 033 623

TOTAL ENERGY MANAGEMENT
A Practical Handbook on Energy Conservation and Management

Developed by

National Electrical Contractors Association

NEMA

National Electrical Manufacturers Association

In Cooperation with the

Federal Energy Administration
(Now U.S. Dept. of Energy)

Endorsed by

Edison Electric Institute

Department of Commerce

NAED

National Association of Electrical Distributors

BOMA
INTERNATIONAL

Building Owners and Managers Association, International

FOR USE OF OWNERS AND MANAGERS OF OFFICE BUILDINGS AND SMALL RETAIL STORES

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OVERVIEW

TOTAL ENERGY MANAGEMENT— A VOLUNTARY, FLEXIBLE PROGRAM FOR SAVING ENERGY

The vast majority of commercial buildings in the United States were designed and built during times when conservation of energy did not command the urgency it does today. Conditions have changed dramatically and attempts now are being made to modify these buildings so their operation requires less energy.

Total Energy Management (TEM) is an energy conservation approach based on the premise that each building should be looked at in terms of its total energy consumption, rather than in terms of prescribing energy budgets for its separate and discreet systems. To accomplish this, each system of a building should be brought to its maximum efficiency, but because each building is unique, trade-offs or options can be made in the total energy used, depending upon the wishes and the needs of the building's owner or manager. Therefore, a building's optimum energy efficiency is not necessarily related to a specific total energy budget. But the measurement of an existing building's efficiency is indeed related to its past performance.

This approach is performance oriented for the total building in that the TEM goals are measured in total Btu's per gross conditioned square foot. The steps to achieve these goals, however, often involve prescribing procedures for particular subsystems.

TEM, therefore, provides owners and managers the flexibility required to conserve energy and cut costs while at the same time meeting the needs of the building's users.

Accomplishment of TEM goals requires that the building owner be committed to the concept of energy conservation. Based on this commitment, he will be able to set into motion the management techniques required to establish a TEM program.

Initial efforts involve review of the building's past energy consumption characteristics and development of an Energy Utilization Index (EUI) which indicates how much energy (in Btu's) the building consumes per gross conditioned square foot.

Once the EUI is established, a comprehensive building energy audit is undertaken to determine where opportunities for energy conservation exist. In many cases significant energy waste can be eliminated through repair of faulty equipment and improved maintenance and operating practices. Numerous other options are available, some requiring little change from current procedures, others involving modifications much broader in scope.

Following review of the methods available to turn opportunities into actual savings, it is management's responsibility to establish priorities. In so doing, it must consider time and budget available, specific user needs, and related business and productivity considerations unique to the building. It will be seen at this time that implementing many of these conservation techniques, although they involve minimal expense, will achieve significant energy and operating cost savings.

Once specific conservation measures are identified and priorities set, management establishes an action plan which spells out what is to be done; when it is to be done, and who is to do it. For maximum effectiveness, the plan should cover a five-year period. Specific planning should relate to the first 18 months. For subsequent periods planning must be more general.

Review of the plan will provide information on how much energy can be saved. A plan will ensure that all persons involved are heading in the same direction, and help develop "team spirit."

At the end of six months, plans can be compared with results. Based on this analysis, planning for subsequent periods can be modified if necessary. Additional planning for future periods may be developed. In this way, an effective five-year plan with long-range implications continually reflects current circumstances.

Management personnel, maintenance and operating personnel, and building users all should be kept abreast of TEM activities to reinforce the team effort. All the while, progress of the program must be monitored to ensure optimum results.

The ultimate objective of the TEM program is to bring a building's systems to peak efficiency and to maintain that efficiency through continuing management efforts.

ACKNOWLEDGEMENTS

Many individuals, firms, associations, and public agencies have given generously of their time, talent and experience to assist in development of this publication. Although space prohibits mention of all those involved, special thanks are due to members of the Building Owners and Managers Association International; the Philadelphia Electric Company, and the Philadelphia Gas Works.

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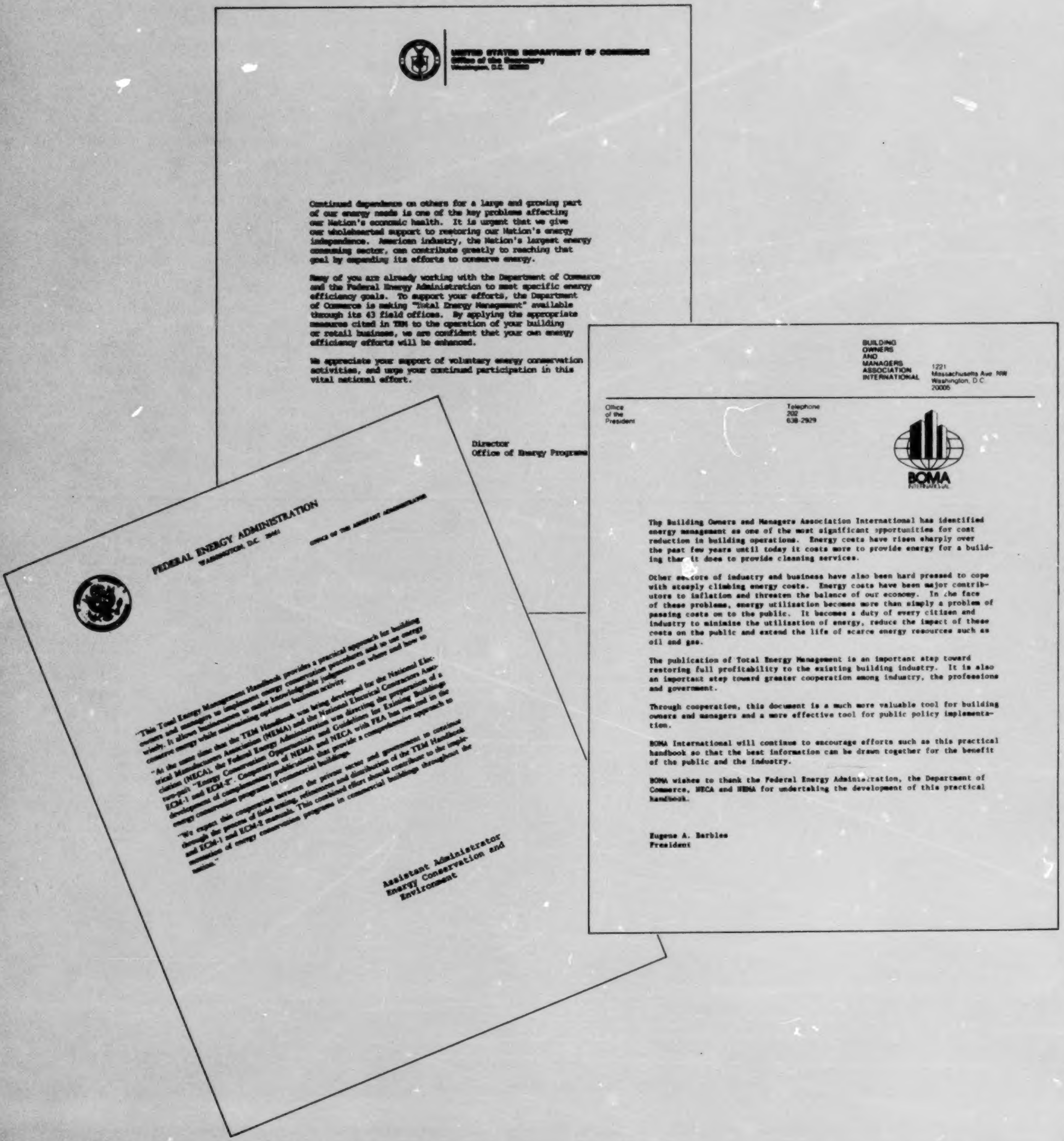

UNITED STATES DEPARTMENT OF COMMERCE
Office of the Secretary
Washington, D.C. 20230

Continued dependence on others for a large and growing part of our energy needs is one of the key problems affecting our Nation's economic health. It is urgent that we give our wholehearted support to restoring our Nation's energy independence. American industry, the Nation's largest energy consuming sector, can contribute greatly to reaching that goal by expanding its efforts to conserve energy.

Many of you are already working with the Department of Commerce and the Federal Energy Administration to meet specific energy efficiency goals. To support your efforts, the Department of Commerce is making "Total Energy Management" available through its 43 field offices. By applying the appropriate measures cited in TEM to the operation of your building or retail business, we are confident that your own energy efficiency efforts will be enhanced.

We appreciate your support of voluntary energy conservation activities, and urge your continued participation in this vital national effort.

Director
Office of Energy Programs

FEDERAL ENERGY ADMINISTRATION
WASHINGTON, D.C. 20461
OFFICE OF THE ASSISTANT ADMINISTRATOR

"This Total Energy Management Handbook provides a practical approach for building owners and managers to implement energy conservation procedures and to use energy wisely. It allows businessmen to make knowledgeable judgments on where and how to conserve energy while maintaining optimum business activity.

"At the same time that the TEM Handbook was being developed for the National Electrical Manufacturers Association (NEMA) and the National Electrical Contractors Association (NECA), the Federal Energy Administration was directing the preparation of a two-part "Energy Conservation Opportunities and Guidelines for Existing Buildings" ECM-1 and ECM-2". Cooperation of NEMA and NECA with FEA has resulted in the development of complementary publications that provide a comprehensive approach to energy conservation programs in commercial buildings.

"We expect this cooperation between the private sector and government to continue through the process of field testing, refinement and distribution of the TEM Handbook and ECM-1 and ECM-2 manuals. This combined effort should contribute to the implementation of energy conservation programs in commercial buildings throughout the nation."

Assistant Administrator
Energy Conservation and
Environment

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The Building Owners and Managers Association International has identified energy management as one of the most significant opportunities for cost reduction in building operations. Energy costs have risen sharply over the past few years until today it costs more to provide energy for a building than it does to provide cleaning services.

Other sectors of industry and business have also been hard pressed to cope with steeply climbing energy costs. Energy costs have been major contributors to inflation and threaten the balance of our economy. In the face of these problems, energy utilization becomes more than simply a problem of passing costs on to the public. It becomes a duty of every citizen and industry to minimize the utilization of energy, reduce the impact of these costs on the public and extend the life of scarce energy resources such as oil and gas.

The publication of Total Energy Management is an important step toward restoring full profitability to the existing building industry. It is also an important step toward greater cooperation among industry, the professions and government.

Through cooperation, this document is a much more valuable tool for building owners and managers and a more effective tool for public policy implementation.

BOMA International will continue to encourage efforts such as this practical handbook so that the best information can be drawn together for the benefit of the public and the industry.

BOMA wishes to thank the Federal Energy Administration, the Department of Commerce, NECA and NEMA for undertaking the development of this practical handbook.

Eugene A. Barbles
President

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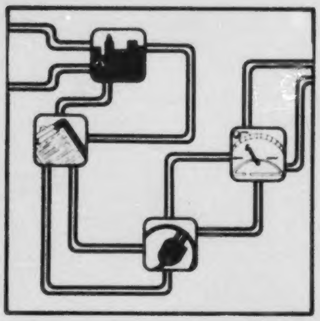

I. INTRODUCTION

Until the early 1970's, many persons in the United States considered energy to be both inexhaustible and expendable. These assumptions were seemingly verified by the relatively low cost of most energy forms. The problems fostered by such attitudes are manifested in commercial buildings. Typically, most such buildings were designed and constructed with initial costs in mind. The result has been creation of a vast inventory of commercial buildings which — by today's standards — utilize excessive amounts of energy.

Buildings being designed now and those to be designed in the future will utilize many new techniques and systems which can lead to maximum energy efficiency. But the present building inventory is being replaced at the rate of only 2-3% per year. As a result, the majority of existing commercial buildings for many years to come will be those designed without energy conservation in mind.

Because of this situation, conservation of energy in existing commercial buildings has become a matter of serious concern. Because energy is critical to the functioning of our nation, the federal government has become involved through the Department of Energy and many other departments and agencies. The government also has been working with organizations in the private sector to develop ways to help spur energy conservation in existing structures.

Shortly after imposition of the 1973-74 OPEC oil embargo, two building energy conservation methods were advanced.

The first method involved implementation of specific end-use restrictions in buildings. This approach requires, for example, adjustment of thermostats to specific levels to use less heating and cooling energy, or removal of electric lamps and luminaires to reduce consumption of lighting energy. Ease of initial implementation is the primary advantage of such an approach. After all, it requires very little new education or effort to adjust a thermostat setting or remove a lightbulb. Unfortunately, the end-use restriction method has numerous drawbacks.

Key among them is this: the extent to which a system is used has no bearing on its efficiency. If for whatever reason, a system is inefficient, it will waste energy every time it is used. End-use restrictions fail to take into consideration the systems which produce the end-use product, be it heating, cooling, or lighting. In other words, end-use restrictions tend to ignore the significant energy savings which can be realized by making systems operate as efficiently as possible. In a similar manner, end-use restrictions fail to consider the fact that every building is a unique system where many elements interrelate. As a result, lowering a thermostat in winter can sometimes cause consumption of more energy, not less. Likewise, removing lamps and luminaires can sometimes cause consumption of those energy sources which are in the shortest supply.

The second energy conservation approach is called Total Energy Management, or TEM. In essence, TEM considers every building as a unique, complex system. To conserve energy one first must understand how the building consumes energy, how users' needs are met, how the systems and their elements interrelate, how external environment affects it, and other factors. By understanding how a specific building consumes energy, energy conservation improvements can be made which can be integrated into the system itself. Then, when the system is used, it runs efficiently and uses the least amount of energy to get the job done.

Application of certain end-use energy modifications—which are an integral element of the TEM concept when applied flexibly and as part of the overall plan—would result in even more savings. Of equal importance, the TEM approach involves literally hundreds of different options from which building owners/managers can pick and choose to achieve energy savings. This gives them the flexibility needed to conserve energy while still meeting the specific needs of buildings and their occupants.

Analysis of the many different techniques which can be used to implement a TEM approach has required extensive research, testing and evaluation. However, the effort has proved worthwhile. More and more building owners and managers are applying TEM, and achieving the many benefits inherent in its application. One such benefit is the cost element. As even a brief review of the options in this manual will show, many of the most effective energy and energy cost conservation measures require little or no capital outlay. In fact, case study after case study has shown that significant energy savings can be obtained through minor operational

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changes, improved maintenance, repair of faulty equipment, and other simple procedures. And, while the program itself cannot be established overnight, putting in the time and effort required in the beginning can result in many elements of the program requiring little or no attention or effort later on.

As you begin reading the contents of this publication, it will become apparent that many of the specific concerns addressed by TEM are not new. What is new is the manner in which they are addressed and the methodology suggested for effective implementation. Perhaps most important, utilization of the TEM approach will enable building owners and managers to realize significant energy and energy cost savings without having to make any significant changes in the working environment each building must support.

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II. ENERGY CONSUMPTION IN BUILDINGS

If an attempt to achieve energy conservation is to be successful, it must be made in full light of the many factors which affect energy consumption. Unless these factors are known and understood, changes made may result in achievements far short of expectations or may actually do more harm than good.

Energy use in buildings is determined, basically, by climatic conditions of the area in which the building is located and the working environment and business equipment required by tenants. Neither of these factors can be modified significantly.

The efficiency of energy use is determined by the three basic systems which comprise any functioning building. These are: *energized systems*, such as those required for heating, cooling, lighting, ventilation, conveyance, business equipment operation, and so on; *nonenergized systems*, such as floors, ceilings, walls, roof, windows (glazing), etc., and; *human systems*, comprising maintenance, operating and management personnel as well as tenants and other users. Each of these three systems can be modified to achieve a significant saving of energy. Because energized systems are those which utilize energy directly, the natural tendency is to concentrate energy conservation efforts in that area. To do so would be a mistake, however, because the efficiency of the equipment involved depends on numerous other factors. In other words, it can be very detrimental to a program of energy conservation to confuse the ends with the means.

Effective energy management requires that the entire pattern of energy consumption be analyzed so that changes made will be integrated into the system in full light of the interrelationships which exist and the various effects which will occur. Accordingly, the following discussion is presented to provide you with a basic understanding of certain critical factors and the way in which they interact.

It is appropriate to begin with the subject of heating and cooling since together they usually consume the largest single "block" of energy.

To start, one should not think of heating and cooling simply in terms of adding or removing heat from the inside air to achieve a given temperature. To do so would ignore what really is involved in heating and cooling, namely, compensating either for heat loss or heat gain in a building. By considering heating and cooling in this light, it becomes evident that modification to heating and cooling can be directed at the heating and cooling system itself, as well as those factors which contribute to heat loss and heat gain.

Heat loss and heat gain usually occur simultaneously in a building, although one usually far outweighs the other depending on the season involved. A building usually undergoes substantial heat loss during the heating season and substantial heat gain during the cooling season. Although climatic conditions — temperature, humidity, wind, solar radiation — are essentially responsible for this effect, the impact of these conditions can be modified substantially, as will be discussed.

The factors which influence heat gain and heat loss are as follows:

Infiltration: Infiltration involves passage of outside air into the building through apertures such as cracks around windows and door jambs, or doors left open. The amount of infiltration depends largely on the impact of the wind on the building (pressure) and the integrity of construction. In large multistory buildings, infiltration is increased due to a vacuum effect which occurs when warmer air — which is lighter — rises to the upper portions of the building. During the heating season, infiltration contributes to heat loss because cold infiltrated air must be heated to maintain desired comfort conditions. During the cooling season, infiltration contributes to heat gain because the warmer infiltrated air must be cooled to maintain desired comfort conditions.

Transmission: Transmission refers to the amount of heat transmitted into the building or from it through the various components of the building envelope, including exterior walls, windows, and doors; roof; and floor. Transmission contributes to heat gain or heat loss depending upon the difference between indoor and outdoor temperature in accordance with the basic principle of heat flow. This principle states that heat always is conducted from an area of higher temperature to an area of lower temperature. Thus, during the heating season, indoor heat is transmitted through the walls to the exterior. The rate of transmission depends upon the composition of the various materials utilized in construction of the building envelope.

Ventilation: As with infiltration and transmission, ventilation contributes to heat gain or heat loss depending on the season involved. The ventilation system provides a building with fresh air by exchanging inside air for outside air. The rate of exchange is measured in cubic feet per minute(CFM). During the heating season, unconditioned cold air is brought into the building while an equivalent volume of warm air is exhausted. During the cooling season, cooled air is exhausted while warm air is brought in. Obviously, the greater the rate of ventilation, and the greater the difference between outside and indoor temperature, the more energy will be consumed by the heating or cooling system to compensate for the heat gain or heat loss involved.

Lighting: Lighting contributes to a building's heat gain in direct proportion to the wattage of the lamps involved. The heat gain involved is beneficial during the heating season in that the heat from light sources and their auxiliaries supplements the heating system. During the cooling season, however, the cooling system must compensate for the "heat of light."

Solar Heat: Solar heat, like the heat of light, contributes to heat gain throughout the year. The specific effect of solar heat depends on factors such as the geographical area involved, the intensity and direction of the rays, the materials which comprise the building envelope, the color and texture of exterior walls and roof, extent and type of solar controls, and available shading.

Equipment: Virtually all powered equipment such as business machines, cooling equipment, appliances, and building systems equipment contributes to heat gain because their motors or other elements generate heat.

Occupants: The number of people in a building or in a given area of a building can create a significant heat gain, because human beings give heat to room air whenever the temperature around them is below body temperature. They also contribute to the moisture content of air through perspiration and exhalation.

A building's total heat loss is equivalent to the amount of heat which the heating system must add to a given space in a given time to maintain a given temperature. The total heat gain is the amount of heat which the cooling system must remove from a given space in a given time to maintain a given temperature. In almost all cases, those factors which contribute negatively to heat loss and heat gain can be modified to a greater or lesser extent. Modification can reduce the load placed on heating and cooling equipment and so the energy required for the equipment's operation. Accordingly, while setting the thermostat to a lower or higher temperature than otherwise would be maintained may achieve savings, reliance on this technique alone could obscure the fact that additional savings—perhaps twice as great or more—could be achieved by modifying other factors, regardless of what temperature is desired.

Modifying heat gain/heat loss factors is not the only method available for reducing the amount of heating and cooling energy required. Adjustment and modification of the heating and cooling equipment itself can achieve substantial economies. It has been shown, for example, that heating and cooling systems of even the most modern buildings often have extensive inefficiencies, usually due to faulty installation, maintenance or operation. Correction of these inefficiencies—which will not require any significant expense—can result in substantial energy savings. Other modifications also can be made. Time clocks can be added to achieve automatic night and weekend setback for certain pieces of equipment. Controls can be added to regulate ventilation equipment more efficiently. New devices can be installed to transfer heat or cooling from exhaust air to incoming air. In all cases, however, all modifications musts be made in light of the various building systems involved and their effect upon each other. For example, certain energy conserving devices and techniques cannot be used because they may cause malfunctions of tenant-required equipment, such as computers. Likewise, while the amount of lighting in a given area can be reduced, the extent of reduction depends on the tasks being performed in the spaces involved, the type of persons performing the work, the ability of move desks and other furnishing to take advantage of available light in a more effective manner, the color and texture of walls, and so on. Similarly, more effective maintenance cannot be achieved unless elements of the human systems are in tune. Maintenance personnel are not likely to establish new, effective maintenance procedures unless they have direction from management. Nor are new operating procedures likely to have continuing effect unless those in charge of building operation are continually willing to do the work, and management is willing and able to continually monitor the effectiveness of the work. Human systems also can have an impact on tenant requirements, no so much in terms of changing requirements, but rather in terms of modifying the way in which systems are used to meet requirements. In other words, tenants can be encouraged to turn off lights when a room is unoccupied; to close all exterior doors securely; and to close windows when heating or cooling systems are in operation.

Numerous publications now available can provide you with additional information regarding interrelationships such as those described above. Many more of these interrelationships are discussed or mentioned throughout the body of this handbook. In any event, it is imperative that you — or whoever will be developing your TEM program — understand the specific system interrelationships which exist in your building and which must be taken into consideration to ensure that any measures taken lead to true conservation of energy through maximized total system efficiency.

III. OBTAINING INITIAL COMMITMENT AND COOPERATION

Assuming that you want to proceed toward development of a Total Energy Management program for your building or buildings, it will be necessary to obtain initial cooperation. This is needed not only to obtain the commitment and assistance required for initial tasks, but also to lay the foundation for the cooperation which will be needed in actual implementation of the full TEM program. As with any management endeavor, it is suggested strongly that maximum effectiveness of the overall approach can be obtained only when one executive is selected in the beginning to head the entire project with support from subordinates as necessary. To fragment authority at the top is to confuse the lines of authority and communication stemming from above. This could affect adversely the coordination and cooperation required to implement and continue the program in an effective, expeditious manner.

Owners: Cooperation must be obtained from owners. While they are likely to approve in principle any attempt to conserve energy and energy costs, they may balk at having to put out initial funds for a professional survey (as suggested by this manual). Owners, therefore, must be convinced of the benefits which will accrue as a result of the TEM approach. They must be shown that the expenditure of funds will be a wise investment, especially since some of the most effective energy conservation measures are those which require no capital investment. In certain cases, it may be necessary to "jump the gun" a bit and complete an Energy Management Form (discussed in the following section) which may indicate that the energy consumption of a building is comparatively high.

Managers: Building managers must be committed to the program, and must believe firmly in its effectiveness. If they do not, then the direction which must come from them will not be what is required. Managers have the difficult responsibility of being between owners, who want results, and operating and maintenance personnel who in many cases, will be producing the results. They must strive to develop an overall spirit of cooperation, and to take those actions which are necessary to maintain this spirit throughout establishment and operation of the TEM program. A testing study conducted to determine the effectiveness of this manual and the TEM concept itself shows that when building management, rather than the operating engineer alone, directs the program, far more conservation areas are explored and more actual savings are realized.

Maintenance and Operating Personnel: It is especially important to obtain the cooperation of maintenance and operating personnel early in the project. These are the people who, in large measure, will be implementing many of the required changes. In most cases, these changes will mean altering long established procedures. It is probable, then, that some operating and maintenance personnel will regard initial TEM operation as a questioning of their capability. Experience has shown that when outsiders are brought in to conduct an initial survey they often are met with hostility and evasiveness. To avoid such problems, it may be advisable to explain the undertaking not so much in terms of "doing things better," but rather in terms of "doing things differently." An effort should be made to convince operating and maintenance personnel that they can make a great contribution to energy conservation, that energy conservation can affect all jobs. In some cases, of course, union agreements in force define specifically who is responsible for what, hours of employment, and related factors. When it is found that such agreements will be counterproductive to the goal of energy conservation, an effort should be made to work with the union involved to establish fair and equitable modifications to agreements which will help make maximum energy savings possible.

Clerical Staff: Clerical staff, or whoever is involved in developing base year data for establishment of base year EUI (discussed in the following section), must cooperate to the fullest. They must be willing to spend the extra time which may be required to find all the data required and to be sure that it is accurate. The importance of their contribution must be shown to them. This same attention to detail will be required later during implementation of the TEM concept and when data must be collected and reported on a monthly basis.

Tenants: It usually will not be necessary to obtain the cooperation of tenants during the initial phase of TEM operations unless the data required only can be obtained from them. As the project progresses, however, tenants will be-

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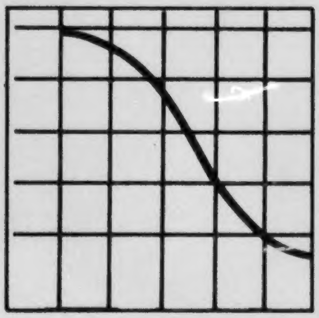
come more and more involved, beginning usually with conduct of the audit, more frequent inspections of facilities, requests for operational modifications and other concerns. In certain cases prevailing lease agreements may set standards which cover matters such as energy consumption and payment, lighting levels to be provided, and heating and cooling conditions to be maintained. When a lease such as this will limit the degree of energy and energy dollar savings possible, the lessor and lessee in cooperation should negotiate lease modifications that will make application of TEM more effective. It should be stressed that changes to be made in the building will not in most cases alter the building's environment. As examples, a lighting system can be kept highly effective — in some cases can be made even more effective — although certain lamps and/or luminaires are removed. Likewise, heating and cooling energy requirements can be reduced substantially without altering the customary temperature in the space involved.

You may find it advisable, once owner cooperation and commitment are assured, to call together all staff personnel — including clerical assistants and operating and maintenance personnel — to explain the undertaking on which you are about to embark; the contribution which can be made to national energy goals and the goals which can be achieved in terms of energy cost savings. In so doing, you also can explain how the cooperation of all individuals working together is essential for completion of the task, and so — by having a group present — instill at once a sense of team spirit which can be invaluable in helping you achieve the goal of energy conservation through Total Energy Management.

IV. ANALYZING BUILDING ENERGY PERFORMANCE



To provide direction for an undertaking, effective management must have a means to measure results and guidance for direction of efforts. Total Energy Management is no different. For a manager to be able to reduce energy use from previous levels, it is, of course, necessary to establish exactly what the previous levels were. Research undertaken by NEMA, NECA and the federal government has shown that an effective way of stating previous levels is in terms of Btu per gross conditioned square foot per year (or month), which is called the Energy Utilization Index, (EUI).

The instrument used to collect the data required is the Energy Management Form shown in Figure IV-1. Although at first glance it may appear to be somewhat difficult to complete, it actually is relatively uncomplicated and straightforward. Moreover, the completed form can become a very valuable component of your TEM program because it is applicable to all areas of planning. Additional applications of the completed form will assist you in areas such as:

Effort Direction: If two or more buildings—similar in design and actual use—are involved, you will be able to compare the different EUIs and so determine quickly which buildings are most and least energy efficient. As a result, assuming a limited budget is involved, you will know where to concentrate initial efforts to achieve the greatest potential savings.

Basis for Comparison: By having consumption records it will be possible to compare energy consumption patterns of a given building for the same period in previous years. Even minor differences can be spotted quickly. As a result, any possible irregularities in utilities' billing or estimating procedures can be identified quickly.

Rate Savings: Establishment of EUI records will provide the information required to determine whether or not a building is receiving the lowest possible utility rates. Electric utilities in particular often have multifactor rate schedules. Changes in the schedule or the building's energy consumption patterns may have made the rate originally established for a building inconsistent with current operations.

Estimating: By establishing the amount of energy used in a previous year, and applying any new energy rates, it will be a relatively simple task to estimate with accuracy the cost of supplying a building with the fuel required for the year ahead. This can be an essential tool in overall cash flow estimation. It can also help operating personnel establish more effective fuel delivery schedules.

Operational Overview: An EUI can quickly establish an operational overview of a given building. Variances from previous months or years can quickly serve to indicate efficiency of building systems. A mechanical problem of one sort or another also may be noticed more quickly through energy utilization data than through actual operation.

The Energy Management Form illustrated is based on a 12-month period. It is suggested for ease of data collection and analysis that a previous calendar year be utilized as the base. Although any 12-month period will do—preferably a 12-month period during which energy conservation measures were not undertaken—the calendar year approach will eliminate potential confusion in data collection and reporting. Initial data required can come either from your own records (assuming utility bill receipts are retained) or from those of the utility involved. If you utilize utility-provided data you will have to establish your base year for the 12-month period for which data is available.

1. DEVELOPING THE EUI

The procedure for recording base-year data and for keeping a running monthly tally for years subsequent to the base year are the same except, of course, that nonbase year data can and should be recorded as it comes in each month.

The various elements of the form shown in Figure IV-1 and computations involved are as follows:

Month (Column 1): Regardless of the billing date used by electric, steam or gas supplier, energy units consumed should be extracted from the bill for that month in which the greatest number of days occurred. If the billing period is March 2-April 2 enter the usage under the month of March.

Heating Degree Days/Cooling Degree Days (Columns 2 and 3): Past studies indicate that daily requirements for space heat and fuel/energy consumption vary directly with the

Fig. IV-1 Energy Management Form

Building ______________________________

Month	Heating Deg. Days	Cooling Deg. Days	Electricity						Purchased		
			kWh	kWh/ Deg. Days	kW Demand		Cost		M (lbs.)	M (lbs.)/ Deg. Days	lbs/hr
					Actual	Billed	Total	Per Ut.			Actual
1	2	3	4	5	6	7	8	9	10	11	12
Jan.											
Feb.											
March											
1st Quarter											
April											
May											
June											
2nd Quarter											
July											
Aug.											
Sept.											
3rd Quarter											
Oct.											
Nov.											
Dec.											
4th Quarter											
Total Per Year											

Building Data

Gross Conditioned Area (ft)^2 ______________________________

Gen. Notes: ______________________________

____

____

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Annual Energy Consumption In Btu

Quantity

1. ______________ kWh
Electricity

2. ______________ (M) lbs
Purchased Steam

3. ______________ MCF
Natural Gas

4. ______________ Gallons
Oil

5. ______________
Other Fuel

____________________ Year

Steam			Fuel							Total Energy Cost
			Oil			Check Gas ☐ Coal ☐ Other ☐			Fuel/ Deg. Days	
Demand	Cost		Quant. (Gal.)	Cost		Quant.	Cost			
Billed	Total	Per Unit		Total	Per Unit		Total	Per Unit		
13	14	15	16	17	18	19	20	21	22	23

	Conversion Fac.		Btu/Yr
X	3413	=	________
X	1,000,000.	=	________
X	1,030,000.	=	________
X	#2- 138,700 #6- 149,700	=	________
X	________	=	________
	6. Total		________

Energy Utilization Index

$$EUI = \frac{\text{Total Energy Consumption Btu/yr}}{\text{Gross Conditioned Area (ft)}^2}$$

$= \_\_\_\_\_\_\_\_\_\_\_\_ \text{Btu/ft}^2\text{/Yr}$

difference between 65°F and the outdoor, mean daily temperature. The outdoor mean daily temperature is the average of the maximum and minimum outdoor temperature during the 24 hours of a given day. For example, if the maximum temperature during the day is 55 degrees and the minimum is 35 degrees, the mean would be 45°F. The heating degree days involved would be 20 (65°F-45°F). If there are 30 days in the month, and each has 20 degree days, total degree days for the month would be 600 (20 × 30). Cooling degree days are determined in the same manner, although it is readily admitted that many other factors—such as humidity, solar conditions and wind—play a significant role during the cooling season. Until such time as an accurate index is established, however, cooling degree days will have to suffice. It should be noted that EUI figures may be calculated for any given month. Monthly EUI data can be extremely useful for monitoring the effectiveness of any energy conservation technique employed. The information is inserted here because it provides a basis for comparison. For example, it would be unfair to compare the EUI of January 1980 to the EUI of January 1981 if January 1980 was twice as cold as January 1981. Information on the number of degree days in your area for each month usually can be obtained from your local electric or gas utility, oil distributor, or the U.S. Weather Bureau's local climatological reports which are issued monthly and are available for a nominal amount. Normally, heating degree day entries will be made for the months of October through May. Cooling degree days usually include the months of June through September.

Electricity – Kilowatt Hours (kWh) (Column 4): Under this column, enter the kilowatt hours shown on the electric utility bill for the appropriate month involved.

Electricity – Kilowatt Hours per Degree Day (Column 5): If electricity is used for heating, note the product of dividing kWh for heating month by the number of heating days involved. If electricity is used for cooling, divide the kWh for cooling month by the number of cooling degree days. In either case, as efficiency increases, the product decreases.

Electricity – kW Demand – Actual (Column 6) and Billed (Column 7): Electric charges for larger facilities usually are broken into two major components—the amount of electricity used (kWh) and the rate of electricity used (kW) over a preselected short period of time, usually 15 to 30 minutes. The greatest level of demand is registered during peak periods, when several major pieces of equipment are operated simultaneously. Changes for the amount of electricity used (in kWh) are based on the cost of generation of electricity. Demand charges reflect the fixed investment which a utility has in the distribution, transmission and generating equipment which must be available to meet your peak demand. In many cases, actual and billed demand are different. Actual demand is a record of what your demand really was during the month. Billed demand is the actual demand adjusted by the various rate provisions and is the demand used for the computation of charges. In Philadelphia, for example, demand rate for schedules PD and HT are billed in accordance with this provision: "During the eight months of October through May, the billing demand *will not be less* than 40% of the maximum demand specified in the contract, *nor less* than 80% of the highest billing demand in the preceding months of June through September." Given the way in which the rates are structured, use of the EUI will enable you to establish during which months an effort should be made to reduce demand and demand charges. For example, in Philadelphia, highest demand usually is recorded in July or August. If demand during both these months can be reduced, then demand charges for heating months (wich cannot be less than 80% of the highest billing demand") will be lowered. Be certain to enter actual and billed demand in the correct columns. (Many smaller facilities do not pay a separate demand charge. In such cases, columns 6 and 7 should be left blank.)

Electricity – Cost – Total (Column 8): Enter the total cost of electricity for the month involved.

Electricity – Cost – Per Unit (Column 9): Obtain per unit cost by dividing total cost by kWh. This will enable you to compare costs of different months or of different buildings. This provides a possible means for determining if a billing error was made.

Purchased Steam – M (lbs.) (Column 10): Enter total steam consumption (in terms of thousands (M) of pounds) as shown on the bill.

Purchased Steam – M (lbs.) – Degree Days (Column 11): If steam is used for heating and/or cooling, divide quantity of steam by appropriate heating or cooling degree days, as for kWh.

Purchased Steam – Lbs./Hour Demand – Actual (Column 12): Enter actual demand as shown on the bill.

Purchased Steam – Lbs./Hour Demand – Billed (Column 13): Enter billed demand as shown on the utility bill. The difference between actual and billed demand is essentially similar to the difference involved for electricity.

Purchased Steam – Cost – Total (Column 14): Enter total cost as shown on the bill for the appropriate period involved.

Purchased Steam – Cost – Per Unit (Column 15). Divide total cost by quantity (M (lbs.)) and enter.

Fuel–Oil–Quantity–Gallons (Column 16): Enter the amount of fuel oil actually *consumed* during the month, which is not necessarily the amount purchased. By knowing how much was on hand at the beginning of the month, how much was added, and how much was left at the end of the month, you will be able to determine the consumption factor.

Fuel – Oil – Cost – Total (Column 17): Multiply the per gallon cost shown on the bill by the amount of oil used during the month.

Fuel – Oil – Cost – Per Unit (Column 18): Enter the per unit cost shown on the bill.

Other Fuels: Enter as appropriate (in Columns 19, 20 and 21) the total monthly amount for each additional form of fuel—such as natural gas or coal—and calculate total cost and per unit cost as shown for electricity or oil.

Fuel – Fuel/Degree Day (Column 22): Make the necessary computation (total amount of fuel divided by number of degree days) and enter the result only if one of the "other" fuels is used for heating and/or cooling. Divide quantity of fuel used for heating during a heating month by the number of heating degree days for the month. Divide quantity of fuel used for cooling during a cooling month by the number of cooling degree days for the month.

Total Energy Cost (Column 23): Add Columns 8, 14, 17 and 20 and enter.

Building Data: The essential data required here is the gross conditioned (heated and/or cooled) square footage of the building involved. Gross conditioned square footage is determined easily by measuring inside wall-to-wall distance of each floor, including the basement (if conditioned). To determine gross conditioned square footage of the building simply add together the gross square footage of conditioned area on all floors. Other information you may wish to insert here — or in a separate notebook — could relate to building systems, equipment and operations, deviations from normal modes of operation (which could explain differences in energy consumption patterns), etc.

Btu Conversion: Annual energy consumption is determined easily by multiplying the total annual amount of a given energy form (Columns 4, 10, 16, and 19) by the appropriate conversion factor. The result in each case is the Btu equivalent of energy consumed. Add together to determine total Btu consumed for the year.

Energy Utilization Index: Energy utilization index (Btu per gross conditioned square foot per year) is determined easily by dividing total annual energy consumption in Btu consumed by the total gross conditioned square footage of the building. As mentioned above, EUIs can and should also be determined on a monthly basis.

2. CLIMATIC ADJUSTMENT

As already mentioned, it is difficult to compare energy consumption from one year to the next without taking into consideration those varying climatological factors — temperature, wind, humidity, precipitation, cloud cover, etc. — which have an impact primarily on a building's heating, ventilating and cooling system. What is needed, obviously, is some means whereby climatological factors can be indexed and then integrated with consumption data so energy consumption in the base year, or during a portion of the base year, can be compared to a subsequent year or period on the basis of identical climatological conditions. Although a substantial amount of research is going on to develop some type simple conversion factor or easily utilized tables and charts, none now exists. As a result, you should rely on one of two methods which can result in a reasonable basis for comparison.

The first method is to contact your local gas or electric utility. In most cases both have material on climatic factors readily available and utilize the degree day method — adjusted for local conditions — to determine their own future requirements. Chances are members of the utility's energy management staff can review data concerning your building and give you a reasonably accurate appraisal of how your EUI data can be adjusted for the impact of weather.

The second method, which can be used in conjunction with the first, requires you to gather historical energy consumption data on your building perhaps for the past five years. You probably will be able to rely on your own records and those which the utility may have. Obtain data on heating and cooling degree days for your area for the same period from the National Climatic Center, Asheville, North Carolina. Analyze the relationship between heating and cooling degree days (and other weather factors) and energy consumption in your building (assuming that the HVAC system, load and operating and maintenance practices have remained relatively unchanged over the period under review). The more detailed your review, the more factors which can be considered and the more accurate your adjustment can be.

3. OTHER ADJUSTMENTS

More than climatic adjustment may be needed to help ensure that EUI comparisons for different periods are reasonably accurate. Three basic factors are involved.

The first set of factors relates to the number of tenants. If during one period there were fewer tenants than in other periods, the reduced HVAC and lighting energy consumption caused by vacancies must be considered. There is no rule of thumb for making this type of adjustment. Records must be reviewed and adjustments must be approximated.

The second set of factors relates to usage. For example, if a tenant installs or removes energy-intensive equipment, energy consumption will be affected. Again, a review of records is needed to determine when such changes were made and their approximate effect on energy consumption.

The third set of factors relates to hours of occupancy. Major changes can occur especially when electronic data processing equipment is installed. In many cases, data processing operations will run on 16- or 24-hour shifts, as opposed to 8-hour shifts. While the equipment itself may not be responsible for substantial energy consumption, large amounts of energy may be used to support workers' "after-hours" needs, such as heating, cooling, ventilation, and lighting. A review of records will indicate the types of adjustments which are appropriate.

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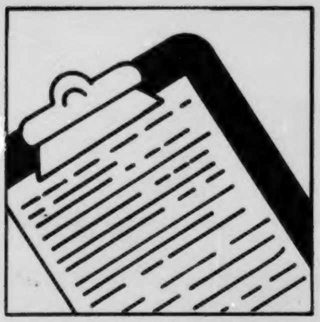
V. CONDUCTING AN ENERGY AUDIT



Performance of an energy audit is absolutely fundamental to the successful development and implementation of a TEM program. It is essential that the audit be made by persons who know exactly what they are looking for and who can present findings in an unbiased manner. It is suggested that the program be conducted in a professional manner by an energy expert such as a qualified electrical contractor or a consulting engineer. Whether the audit is conducted in-house or by a consultant, those performing it must be expert enough to recognize a possible source of wasted energy. Contractors or engineers, because of their extensive experience and diversified knowledge, may recognize that the way in which the specific function is being conducted could be altered to provide significant savings. Likewise, consultants may note that maintenance is not being performed as it should be and may recommend procedures which can provide better direction. You may, of course, want to have in-house personnel undertake the audit. For this reason, the discussion presented in the following section provides, in addition to other materials, information on what to look for when making an audit. Much of this information can be recorded in a form such as shown in Appendix A.

Energy audits can be grouped into two categories: *walk-through energy audits* and *detailed energy audits*. There are no specific requirements which separate the two. Hybrid approaches are commonplace. The objective is to identify areas of waste and inefficiency and to discover Energy Conservation Opportunities (ECO's).

1. WALK-THROUGH AUDIT

A walk-through energy audit usually begins with a review of a building's energy consumption over a prior period, usually the previous year. It is best for this information to be prepared in the form of an Energy Utilization Index (EUI), already discussed.

The walk-through is performed best by a team, consisting usually of an energy management consultant and the director of the physical plant. A representative of management may go along as well.

Two types of information should be recorded.

The first type identifies what is installed, how the various systems consume energy, and easily-obtained data—as from nameplates — needed to form the basis for recommending specific energy conservation opportunities.

The second type of information relates to the evident conditions of systems and subsystems and, as appropriate, ECO's which are suggested by virtue of conditions. Thus, a typical notation might read:

Exterior West Facade: Window does not close properly. Repair window. Caulk around window frame.

Typical concerns which may be covered by a walk-through audit include: reduction of infiltration/exfiltration; quality of maintenance apparently being performed on HVAC equipment, including controls; lighting system ECO's; ventilation system operation, control and opportunities for improvement, and tenant use practices.

Walk-through energy audits are geared to identifying only that which is most obvious. Most substantial energy savings can be identified only through more thorough investigation.

2. DETAILED ENERGY AUDIT

The exact parameters of a detailed energy audit depend on the size of the building, the complexity of its systems, and the budget allocated for the purpose. It is suggested that the consultant work with the building's owner or manager to arrive at a negotiated agreement as to what is required. Generally speaking, the more comprehensive the audit is, the more valuable insights into conservation opportunities and cost savings it will provide. The following discussion is intended to highlight some of the basic procedures usually involved.

2.1 Assemble The Team

The first step is assembling the team, and identifying the functions of individual participants. Some, such as a representative of the electrical utility, may provide additional assistance completely off-site.

The persons involved include:

2.1.1 Design Professionals

On less complex buildings, a competent consultant or contractor with electrical engineering capability and some background in mechanical engineering (or vice-versa) will be able to provide assistance. In larger, more complex buildings, a consultant with full mechanical *and* electrical engineering expertise will be needed. He should act as the team leader.

It may be appropriate to have an architect on the team as well. On less complex projects, an architect who is well versed in both mechanical and electrical engineering feasibly could be the sole design professional needed.

Depending on the experience of others, assistance from a qualified illumination engineer may be valuable, especially so if relatively little has been done previously to modify the lighting system, and a substantial percentage of overall energy expense can be attributed to lighting.

2.1.2 Qualified Contractors

A reputable contractor with experience in energy management, may substitute for a design professional. Many members of the National Electrical Contractors Association have extensive training and experience in energy management. Contractors also can provide information on the latest technology, products and materials, the cost to purchase and install them, their actual performance in the field, and their relative ease of operation and maintenance.

2.1.3 Building Ownership/Management Representatives

Representatives of a building's ownership and/or management are needed, at least to ensure that various internal concerns are handled properly. For example, development of energy consumption data depends on cooperation from operating and maintenance personnel and access for after-hours observation.

When appropriate, management representatives should explain details about prevailing lease agreements as they affect access to key areas, pertain to cost-sharing of modifications, and impact on other areas involved in the TEM Program.

2.1.4 Operating And Maintenance Personnel

The director of the physical plant or the chief operating engineer should accompany members of the project team on most of their observation rounds. Members of his staff should be on hand to answer whatever questions may be asked.

It is particularly important that relations with members of the operating and maintenance (O&M) staff run smoothly.

2.1.5 Utility Representatives

Depending on the policies of the local electrical utility, a utility representative may or may not wish to be involved in the on-site inspection portion of the audit. A representative of the fuel oil supplier or gas utility may wish to be involved in inspection of the heating system.

All appropriate utility representatives should be contacted to obtain information on rate structures.

2.2 Obtain Materials For Review

Audit consultants should have certain information on hand before actually visiting a building. Typically, this information includes, in addition to EUI base-year data,:

a. *Energy consumption data for years previous to the base year.* Although it is not critical to the Conservation Program, it is suggested that energy consumption data for the three years prior to the base year also be collected and made available in a useable format for purposes of comparison.

b. *Weather data.* Weather data should be obtained for each year for which energy consumption data are collected. Weather data usually are available from the local electrical utility. Otherwise, they may be obtained from the *National Climatic Center, Federal Building, Asheville, North Carolina 28841.*

   Note: Cooling degree-day data generally are not considered an effective index of cooling requirements because they do not consider humidity factors. The local electrical utility probably uses something other than cooling degree day data. *The key concern is consistency.* The type of data used for the base year should be used for subsequent years.

c. *Building data.* Ideally, auditors will be able to obtain original building plans and specifications, along with as-built plans, either from the building owner/manager or the original consulting engineers or general contractor. If none of these sources can provide what is needed, single line diagrams will be required.

d. *Operating and maintenance logs, manuals.* Review of operating and maintenance logs and equipment manuals can be useful. These references help indicate how equipment is being operated and maintained and how changes in equipment performance have been dealt with by changes in O&M routines.

e. *Utility rate schedules.* Rate schedules should be reviewed to determine if the building is obtaining the best rate or if modifications could result in obtaining a better rate. Utility representatives should be asked to indicate likely future rate changes. For example, will utility policy change with regard to demand metering equipment, thus suggesting the use of equipment which is not dependent on the utility-provided demand meter's end-of-interval pulse? Likewise, are rate schedules likely to be restructured, for example, converting to time-of-day metering or a flattened rate approach?

f. *Other.* Other information may be available which will assist in the auditing procedure. For example, in-house personnel may already have initiated certain energy conservation modifications. If so, details should be obtained along with plans for any future modifications. Information should be sought from management on any changes they have planned. Particular importance should be given to any major tenant turnover anticipated or physical modifications such as renovation, remodeling, or expansion. Other information needed relates to codes with which the building must comply, as well as still effective warranties and guarantees on equipment which may be modified.

2.3 Review Information

Information from each source should be reviewed separately and as it interrelates with other sources.

The most obvious correlation is that between energy consumption data and climatic conditions. Are certain trends evident? Are there major changes in consumption data which cannot be explained by the weather? If so, do O&M logs reveal a possible cause? Do O&M logs indicate that certain procedures have been changed? If so, do energy consumption data, correlated with climatic data, indicate difference: What about electrical demand? Do "peaks" and "valleys" occur in a somewhat uniform pattern, or are there unexplained phenomena which bear investigation?

A review of these materials may raise questions which require follow-up. These concerns should be discussed with management and/or the head of O&M prior to the on-site investigation.

2.4 On-Site Investigation

The various components of an on-site investigation are as follows:

2.4.1 Testing And Measurement

Although testing and measurement may not be cost-effective in smaller, less complex facilities, they are extremely desirable in larger, more complex buildings which spend $100,000 or more for energy each year.

2.4.2 Systems Inspection

Since energy consumption in buildings is determined by the characteristics and interactions of the three basic systems, information on all three should be obtained during inspection and monitoring of operations.

When equipment is inspected, basic information should be recorded to identify what specific type of equipment is installed, its manufacturer, model number, nameplate ratings, current condition and other factors as appropriate.

The degree to which inspection of nonenergized systems such as the building envelope reveals information depends on the skills, knowledge and experience of those performing the inspection. This is one reason why the auditing team should represent diverse backgrounds and capabilities.

Performance of O&M personnel can be assessed during inspection of areas in which they are active, and through a review of logs. Standing over an individual while he works will generally inhibit his performance; this approach is not recommended. If it is absolutely necessary, arrange beforehand for a specific demonstration or explanation of how a given task is performed. The same applies to other elements of the "human system." In an office area, for example, a simple memo could be circulated indicating that energy auditors will be present for a certain period of time. Typical observations could center on how people operate their equipment, lighting, appliances, drapes and blinds, etc. It also is extremely important to observe:

1. When people start arriving for the day;
2. when people leave for and return from lunch;
3. when people start leaving for the day;
4. how many persons usually remain in the building, and for how long, after normal hours;
5. the equipment used after hours, and central systems (heating, cooling, lighting) required for support.

This type of information helps determine optimal start and stop times; whether lighting can be stepped-down or turned off altogether during lunch hours; possible installation of control systems to reduce energy consumption for those working after hours, etc. It can also help identify the types of equipment which could be connected into energy management and control systems performing such functions as demand control, duty cycling, and optimized start/stop.

It also is appropriate to have an energy auditor present in the building during normally-closed periods. This generally involves times when the building is empty (i.e., from 8PM to 6AM) and a Saturday or Sunday.

2.5 Computer Simulation

In larger buildings or those with more complex HVAC systems computer simulation or computer modeling may be called for. A variety of different programs is available, some considered more accurate than others.

Most of the simulation programs available receive initial input in the form of data relating to installed systems and climatic conditions. The print-out should provide a reasonably accurate estimate of monthly and annual energy consumption. If monthly or annual data are not reasonably accurate, the cause must be determined. Obviously, simulating modifications to an existing system cannot begin until the program is able to simulate existing performance. Once the program is fine-tuned, it takes relatively little time to determine the likely impact of any given modification or — particularly important — any given combination of modifications.

A comprehensive list of simulation software has been published by ASHRAE, called *Bibliography of Computer Programs*. It may be ordered from: ASHRAE, 345 East 47th Street, New York, N.Y. 10017.

2.6 Report

The audit should result in a thorough report which details each and every energy-wasting flaw in the building's energized systems, nonenergized systems and human systems. The report also should contain a list of ECO's which can be implemented to remedy each flaw, with due consideration for its effects on other building systems. It also may be practical to include the expected cost of such modifications, when costs are involved. In addition, the report should indicate what type of equipment and controls should be added to the various systems. It should detail proposed new procedures, such as development of a lighting schedule, to reduce energy consumption. Total costs involved, projected payback periods and return on investment for these undertakings also should be included. In addition, you also may specify that the audit report indicate priorities in light of factors you establish as criteria.

Whenever a possible change means a significant capital outlay is involved, or if retrofitting may result in closing a portion of the building for a time (or an action of similar impact), it is suggested strongly that the action be justified by a feasibility study. Such studies will provide the full, in-depth information required to base a decision on all relevant facts. While the retrofitting opportunities which are subject to feasibility studies may be mentioned in a report, the feasibility study itself usually is far more detailed, and is prepared subsequent to review of the initial study, in full consideration for other alternatives which exist.

If the report will be developed in-house, consider these guidelines:

a. Determine where energy inefficiencies and waste now exist. This does not imply modifications to the system, but rather those actions which should be taken to bring elements of the system up to the efficiency at which they should function. This in itself can save a considerable amount of energy in most buildings.

b. If a given piece of equipment is operating poorly, determine why. Is it because it needs adjustment, repair or replacement? Is it not being maintained well? Is it being operated improperly? The cause, of course, leads directly to the cure. If poor maintenance seems to be the problem, it would mean that a revised maintenance schedule may be required, or that more instruction must be given, or that the person performing the maintenance should be replaced. Many of the guidelines provided in this manual will provide direction on this subject. At all times, however, consider how any change — even bringing the system up to full operating efficiency — will affect other elements of the same system or other systems.

c. Determine where systems can be modified in accordance with guidelines provided in the following section to achieve greater energy efficiency. In so doing, consider how the modifications should be made and what the effect will be on other systems related to it directly or indirectly.

d. Determine the problems which are likely to occur through implementation of ECO's. The more you can think along these lines and recognize beforehand the stumbling blocks which probably will present themselves later on, the better your chances of avoiding the stumbling blocks completely. Consideration of codes and other regulations is of critical importance. There may be many more than you thought possible, depending on local circumstances, as the following list indicates:

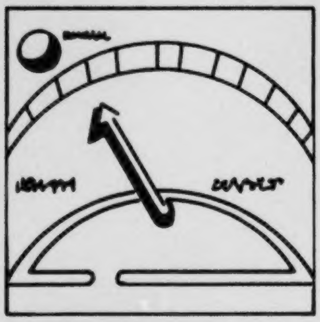
- Building Code
- Electrical Code
- Mechanical Code (Heating, Cooling, Ventilation, etc.)
- Plumbing Code
- Fire Prevention Code
- Elevator Code
- Health Codes
- Occupational Safety and Health Administration Regulations
- Public Utility Regulations (Electricity, Steam, Gas, Water, Sewer, Telephone)
- Air and Water Pollution Regulations

While representatives of each of the agencies involved can be contacted, it may be far easier to utilize a consultant who is familiar with most of these concerns.

e. Establish the cost of each alternative and the possible amount of time it will take to implement it from start to finish.

f. Establish the amount of energy and/or money implementation of each item will save.

VI. GUIDELINES FOR ENERGY CONSERVATION



This section identifies and discusses numerous different Energy Conservation Opportunities (ECO's) which can make office buildings and retail stores more energy efficient when put into effect. Guidelines set forth here can be applied during the audit to establish specific areas for study, as well as for determination of which ECO's should be pursued and the method of doing so. The scope of these guidelines is necessarily broad to provide discussion of the many alternative types of subsystems which could exist in any given building. As a result, some of the items discussed — especially in the area of heating and cooling equipment — may not always be applicable to your particular building. Except as noted, however, most discussion is applicable to both retail stores and office buildings.

The specific alternatives discussed are broken into two categories: MINIMAL EXPENSE and SIGNIFICANT EXPENSE. In certain cases some of the minimal expense items are checkmarked (√) to indicate that they involve virtually no cost at all; have little or no impact on occupant comfort and business productivity, and can be implemented immediately to reduce wastage of energy. Such steps would include, for example, lowering thermostats set at abnormally high levels during the heating season; being sure that lights, equipment, machinery and appliances are turned off when an area is not in use; keeping heat exchanger surfaces and filters clean; and stopping leakage of conditioned air and water, steam condensate, fuel oil and gas. In all cases, such actions — in fact, all energy conservation actions — should be undertaken in a manner consistent with comfort, production, process and other requirements of building occupants.

It must be borne in mind that the cost categories are supplied primarily for reference purposes. While cost is a major factor in establishing which alternatives to pursue, one also must consider the benefits involved. Moreover, cost factors vary from building to building, depending on the extent and capabilities of in-house personnel, accounting methods, and so on.

Before determining exactly which alternatives to pursue, it is suggested strongly that you first identify those alternatives applicable to your building. Since it is unlikely that you will be able to pursue all of them during the first or even second year of your TEM program, it probably will be most effective to determine which group of alternatives — in the aggregate — will fall within budget and yield maximum benefits.

As a last note, recognize that the following discussion addresses itself primarily to components of various systems. This approach has been utilized to reduce needless repetition in that two entirely different systems may have many components in common, such as fans, and motors. Nonetheless, some repetition does exist where required for better understanding of material covered. Use the index to establish all places where a given component or other subject is discussed.

1. VENTILATION

Ventilation has significant impact on a building's total energy consumption. Each cubic foot of air brought into the building must be either heated or cooled and, in some cases, humidified and/or dehumidified. It is generally agreed that many building codes demand an amount of ventilation in excess of what actually is required to provide for the safety and comfort of building occupants. Because many building code officials also recognize this, they often are willing to allow changes to ventilation systems which will drop CFM rates below those nominally required, providing that such changes are not irreversible. Of course, the approval of code authorities must be obtained before you undertake any changes which will result in violation of the applicable codes as written. Guidelines for action are as follows:

MINIMAL EXPENSE

a. Reduce outdoor air to the minimum required to balance the exhaust requirements and maintain a slight positive pressure to retard infiltration-caused heat losses and heat gains.

√b: Inspect all outdoor air dampers. They should be as airtight as possible when closed. Check operation of position indicators for accuracy. Install, repair, or replace position indicators as needed.

c. Reduce or eliminate the need for using outdoor air for odor control by installing chemical or activated charcoal odor-absorbing devices.

√d. Inspect filters carefully. If necessary, create a filter replacement schedule. Utilize high-efficiency, low-cost filters.
√e. Reduce exhaust air quantities as practical.
f. Close outdoor air dampers during the first and last hour of occupancy when the air must be heated or cooled, except when outdoor air can be used to reduce cooling loads.
√g. Establish a ventilation operation schedule so exhaust system operates only when it is needed most.
h. Add a warm-up cycle to air handling units with outdoor air intake. Keep outdoor air dampers closed during morning building warm-up or cool-down so only air already in the building is conditioned. Cycle can be incorporated using a two-circuit time clock to control air damper and fan operation.
i. Use exhaust hoods in food preparation and laboratory areas only while operations are underway. Add control dampers or gravity damper to keep the air path in the exhaust duct closed when fan is not operating.
j. If a food preparation area exhaust hood is oversized, adjust it so no more air than necessary is exhausted. This can be done easily by blocking off a portion of the hood, or reducing fan speed, or lowering hood, or by utilizing a combination of these techniques in compliance with applicable health regulations.
k. Consider cutting off direct outdoor air supply to toilet rooms and other potentially "odorous" areas. Permit air from other areas to migrate into such areas through door grilles and be exhausted.
l. If possible, concentrate smoking areas together so they can be served by one exhaust system.
m. Consider adding controls to shut down the ventilation system whenever the building is closed for an extended period of time, as during the evening, weekends, etc., except when the economizer cycle is in use.
n. Reduce volume of toilet exhausts in buildings which have multiple toilet exhaust fans having a total fan capacity in excess of outside air requirements. This can be done by wiring a fan interlock into toilet room lights through a timed relay, so the fan is activated only when lights are on. An administrative request plus signs to the effect that lights should be turned off when the room is not in use will help ensure that lights (and thus the fan) are off when the room is not being used. Another method involves damping down air volume so only that amount of air required by code is removed.
o. If a large occupant load is involved, consider installing remotely adjustable outside air dampers. These permit outside air volume to be adjusted in approximate proportion to current occupancy.
p. Install baffles to prevent wind from blowing directly into an outdoor air intake.
q. Supply ventilated air to parking garages to levels indicated by CO_2 monitoring system.

SIGNIFICANT EXPENSE

r. Consider installing economizer enthalpy controls to air handling units in offices to minimize cooling energy required by using proper amounts of outdoor and return air to permit "free cooling" by outside air when possible.
s. When more than 10,000 CFM is involved, and when building configuration permits, consider installation of heat recovery devices such as a rotary heat exchanger. For some climatic conditions an "enthalpy wheel," which permits recovery of some 75% of outdoor heat load during both heating and cooling cycles, will be feasible. (See Section 11.1 of this chapter.)
t. Modify duct systems and hoods to introduce unheated outdoor or return air directly to the exhaust hood. Weigh this against changing hoods to new high velocity hoods which require less make up air.

2. INFILTRATION

Unwanted outside air infiltrates into a building through inadvertent openings in the building envelope, such as open doors. Since outdoor air, regardless of source, must be heated or cooled (and sometimes humidified and/or dehumidified), infiltration imposes a significant load on the heating and cooling system, increasing total energy consumption. The problem of infiltration is appreciably worse in tall buildings, which usually must contend with "stack effect." This occurs because of the difference in density between warm indoor air and cold outdoor air. As indoor air is heated it becomes lighter and tends to rise, eventually leaving the building through upper floors. The hot air is replaced by a continual flow of cold air entering the building through any available opening. The upflow of air increases with the height of the structure.

The following guidelines should be observed to inspect for sources of and reduce infiltration, regardless of building height or configuration.

2.1 Windows and Skylights

MINIMAL EXPENSE

√a. Replace broken or cracked window panes.
√b. Replace worn or broken weatherstripping around operable windows. If possible, install weatherstripping where none was installed previously.
√c. Weatherstrip operable sash if crack is evident.
√d. Caulk around window frames (exterior and interior) if cracks are evident.
√e. Rehang misaligned windows.
√f. Be certain that all operable windows have sealing gaskets and cam latches that are in proper working order.
√g. Consider posting a small sign next to each operable window instructing occupants not to open window while the building is being heated or cooled.

SIGNIFICANT EXPENSE

h. Install tightfitting storm windows where practical.

2.2 Doors

MINIMAL EXPENSE

√a. Replace any worn or broken weatherstripping. Install weatherstripping where none has been installed previously.
√b. Rehang misaligned doors.
√c. Caulk around door frames.

✓d. Inspect all automatic door closers to ensure they are functioning properly. Consider adjustment to enable faster closing.

✓e. Inspect gasketing on garage and other overhead doors. Repair, replace or install as necessary.

✓f. Consider placing a small sign next to each door leading to the exterior or unconditioned spaces advising occupants to keep door closed at all times when not in use.

✓g. Consider installing signs on exterior walls near delivery doors providing instructions to delivery personnel on operation of doors.

✓h. Establish rules for all building personnel regarding opening and closing of doors, directing them to keep them closed whenever possible.

i. Consider installing automatic door closers on all doors leading to the exterior or unconditioned spaces.

j. If the building has a garage but does not have a garage door, consider installing one, preferably motorized to enable easier opening and closing.

k. Consider use of a card-, key- or radio frequency-operated garage door which stays closed at all times except when in use.

SIGNIFICANT EXPENSE

l. Consider making delivery entrances smaller. The larger the opening, the more air that infiltrates when doors are open.

m. Consider using an expandable enclosure for delivery ports. It reduces infiltration when in use because it can be adjusted to meet the back of a truck reducing substantially the amount of air which otherwise would infiltrate.

n. Consider installation of an air curtain, especially in delivery areas. The device prevents penetration of unconditioned air by forcing a layer of air of predetermined thickness and velocity over the entire entrance opening. (An expert in the field should be consulted before obtaining such a device, especially when high-rise structures are involved. The degree of stack effect, among other things, determines its usability.)

o. Consider installation of a vestibule for the front entrance of a building, where practical. It should be fitted with self-closing weatherstripped doors. It is critical that sufficient distance between doors is provided.

p. Consider utilizing revolving doors for the front entrance. Studies have shown that such devices allow far less air to infiltrate with each entrance or exit. Use of revolving doors in both elements of a vestibule is even more effective. If high peak traffic is involved, swinging doors can be used to supplement revolving doors.

q. In locations where strong winds occur for long durations, consider installing wind screens to protect external doors from direct blast of prevailing winds. Screens can be opaque, constructed cheaply from concrete block or can be transparent, constructed of metal framing with armored glass. Careful positioning is necessary for infiltration control.

2.3 Exterior Surfaces

MINIMAL EXPENSE

✓a. Caulk, gasket or otherwise weatherstrip all exterior joints, such as those between wall and foundation or wall and roof, and between wall panels.

✓b. Caulk, gasket or otherwise weatherstrip all openings, such as those provided for extrance of electrical conduits, piping, through-the-wall cooling and other units, outside air louvers, etc.

c. Where practical, cover all window and through-the-wall cooling units when not in use. Specially designed covers can be obtained at relatively low cost.

3. HEATING AND COOLING

As already mentioned, heating and cooling together usually consume the largest single "block" of energy utilized by a building during the course of a year. In most cases, however, the heating/cooling system was designed only with initial costs in mind. As a result, the energy efficiency of the system seldom was a design criterion. Moreover, most systems were designed to meet extreme conditions which possibly could occur, but which seldom do. Accordingly, many are oversized and so perform in an inefficient manner.

There are many ways in which heating and cooling systems can be made more efficient. In general, these alternatives can be divided into four categories: operating practices modifications, maintenance modifications, systems modifications, and control adjustment and modifications.

3.1. Operating Practices Modifications (General)

Significant heating and cooling energy savings can be achieved simply by modifying the manner in which heating and cooling systems are operated. Several facts should be emphasized strongly, however:

- Operational savings are limited. While changes in operational procedures can save energy and energy costs, the net amount represents but a fraction of the potential which can be saved through other, more substantive measures. In other words, do not use operational savings as an excuse not to undertake other, potentially more beneficial measures.
- Operational savings will, in some cases, cause minor deviation from accepted standards of comfort. Some deviations may be more noticed than others.
- Professional assistance and guidance should be obtained before instituting any significant operational change. As an example, in certain situations setting a thermostat to 68 degrees during the heating season can cause the cooling system to be activated, wasting more energy than is conserved. (This situation was documented in a 25-story midwestern office building at a cost of $1,000 for three hours of winter cooling.) Likewise, setting thermostats at 78°F during the cooling season can bring on heating or reheat.
- Remember that each building represents a unique situation. As such, the guidelines outlined herein should be recognized as general only. Each must be tailored for the building involved, preferably with professional guidance.

Here follow some of the guidelines for the more effective changes which can be made in operational routine to effect energy savings:

MINIMAL EXPENSE

√a. Reduce use of heating and cooling systems in spaces which are used infrequently or only for short periods of time.

√b. Heat office buildings to 68°F when occupied, 50°-60° when unoccupied. This does not mean that air should be cooled if the temperature exceeds 68°F. Interior office spaces tend to experience significant heat gains due to lighting, equipment and people. Systems serving most areas use a combination of recirculated inside air and some outside air. As a result, the temperature may tend to stay at or above 68°F.

√c. Preheat building so that it achieves 65°F by the time occupants arrive. Complete warm-up during the first hour of occupancy. Lighting, people and use of equipment will aid in warmup.

√d. Turn heat off during last hour of occupancy.

√e. Cool office building to 78°F when occupied. Do not utilize mechanical cooling when unoccupied. Special consideration, however, must be given to computer rooms. Generally, the primary criterion is a constant temperature/humidity relationship. Manufacturers should be contacted to determine permissible ranges. Cooling usually is required when the equipment is operated, but should not be used to lower room temperature below the range of 78°F-80°.

√f. Begin precooling operations so the building is at 80°F by the time occupants arrive. Complete cool-down during the first hour of occupancy.

√g. Maintain retail store sales area temperatures at 68°F during the heating season and at 78°F during the cooling season.

√h. Isolate storage room areas from sales area. Maintain storage areas at 60°F or lower in winter.

√i. Shut off all heating in garages, docks and platform areas.

√j. Consider closing outside air dampers during the first and last hours of occupancy and during peak loads.

√k. During cooling season evening and night hours, flush the building with cooler outdoor air.

√l. Allow natural humidity variations from 30% R.H. to 60% R.H. in occupied spaces.

√m. When appropriate, consider closing supply registers and radiators and reducing thermostat settings or turning off the electric heaters in lobbies, corridors and vestibules.

√n. Where sill height electric heaters are used, adjust thermostat so heat provided is just sufficient to prevent cold downdrafts from reaching the floor.

√o. Turn off humidifiers whenever the building is closed for extended periods of time, except when process or equipment requirements take precedence.

√p. Evaluate the necessity of humidification system and curtail humidification for areas such as hallways, equipment rooms, lobbies, laundry areas, and similar spaces.

√q. Turn off portable electric heaters and portable fans when not needed or during unoccupied periods.

√r. Turn on self-contained units, such as window and through-the-wall units, only when needed. Turn them off when the space is to be unoccupied for several hours.

√s. In mild weather, lower the cooling effect by running room cooling fans at lower speeds.

√t. Turn off all noncritical exhaust fans.

√u. Turn off reheat in all areas during summer, except where equipment requirements necessitate humidity control.

√v. When the sun is not shining during the heating season, close interior shading devices to reduce radiation from body to cold window surfaces.

√w. Develop an after-hours equipment operation checklist for use by custodial and other building personnel as well as occupants who may use various spaces after normal periods of occupancy.

√x. Schedule operating and maintenance work during the daytime, if possible.

√y. Wear heavier clothing during the heating season and lighter clothing during the cooling season.

√z. Reduce internal heat generation as much as possible during the cooling season. Typical sources of heat generation include lighting, people, machines, cooking equipment, etc.

SIGNIFICANT EXPENSE

aa. Adjust and balance system to minimize overcooling and overheating which result from poor zoning, poor distribution, improper location of controls, or improper control.

3.2 Operating Practices Modifications (Central Plant)

Once other changes have been made to affect the building's heating and cooling loads, certain changes can be made to central plant operating practices. The importance of several factors must be recognized:

- Certain operational changes accomplished through manual control also can be made through automatic control. Compare the efficiency and cost of both methods and consider the potential impact of likely future changes before determining which way to go.
- Obtain assistance when required. The complexity, cost and importance of central plants demand that those making changes know exactly what they are doing.
- Be certain to maintain daily operational logs to determine the effectiveness of the system, impact of a modification, and times when additional modifications may be required.

Some of the basic operational modifications which can be made to chillers and boilers are as follows:

MINIMAL EXPENSE

√a. Shut down central heating, ventilating, and air conditioning equipment during unoccupied periods to achieve substantial savings.

Examine building for actual utilization and determine what has to be done to permit maximum shutdown of energy consuming equipment during periods when buildings have few or no occupants: during nights, weekends, and vacation periods. Experience has shown that only a small portion of a building actually requires night or 24-hour operation. Often a small unitary air conditioning system designed to serve a room or few rooms will permit substantial shutdowns of large central systems.

If a central air system provides the only source of heat for a building, maximum use of system capacity probably occurs only during a relatively few hours of the year. As such, a low limit night thermostat can be provided to start the system on a full heating mode with all outdoor air dampers closed to operate as required to keep the building at a temperature such as 50°-60°F. A thermostat of this type is controlled by a time clock which, at a predetermined hour, starts and stops selected fan units and/or opens or closes automatic water or steam valves to maintain the desired temperature. In many cases this unit will have to operate on an infrequent basis due to the thermal storage effects of building energy. As a result, separate convector or radiation hot water systems, in buildings which have them, normally can provide adequate heat during unoccupied periods without operating large central supply air systems. Often these radiation systems can be completely shut off at all temperatures of 35°F to 45°F and above depending on the building envelope involved.

When the HVAC system is de-energized during unoccupied periods, it is essential that outside air dampers be closed tightly. Inspect them to be sure that they make a tight seal. Repair or replace them as required. Likewise, exhaust fans which interlock with outside air fans also should be shut down. The only exceptions to these guidelines would be when an economizer cycle is used at night during the cooling season to use cooler outside air to lower indoor temperature instead of the mechanical cooling system.

If, after shutdown, the cooling system is not capable of achieving and maintaining temperature and humidity conditions in hot spells, install controls to activate the equipment a few hours before occupancy instead of operating the system all night or throughout the entire weekend.

√b. Operate one of multiple compressors and chillers at full load, rather than two or more at part loads.
√c. Operate condenser water system at lower temperatures.
√d. Operate only the chilled water pumps and cooling tower fans necessary.
√e. Elevate chilled water temperatures when humidity conditions permit.
√f. Operate boilers at lower pressure and temperatures in accordance with space heating demand.
√g. Consider elimination of hot standby boilers since, in many cases, a boiler failure will not cause serious hardship.
√h. Operate only the heating water pumps necessary.
√i. Examine operating procedures when more than one boiler is involved. It is far better to operate one boiler at 90% capacity than two at 45% capacity each. The more boilers used, the greater the heat loss.
√j. Check flue gas analysis on periodic basis: the efficient combustion of fuel in a boiler requires burner adjustment to achieve proper stack temperature, CO_2 and excess air settings. Check settings to provide stack temperatures of no more than 150°F above steam or water temperature. There should be no carbon monoxide. For a gas fired unit, CO_2 should be present at 9 or 10%. For #2 oil, 11.5-12.8%; for #6 oil, 13-13.8%.
√k. Adjust air/fuel ratios of firing equipment. The air-to-fuel ratio must be maintained properly. If there is insufficient air, the fire will smoke, cause tubes to become covered with soot and carbon, and thus lower heat transfer efficiency. If too much air is used, unused air is heated by combustion and exhausted up the stack, wasting energy. Most fuel service companies will test your units for a token fee and provide you with specific recommendations.
√l. Use an oil additive to provide better combustion.
√m. Introduce water vapor into the oil before combustion. (Water particles explode when heated, breaking up oil molecules to cause more complete combustion.)
√n. Use automatic viscosity controllers to achieve better oil combustion atomization. Automatic viscosity controllers also permit mixing or using different grades of oil.

3.3 Operating Practices Modification (Kitchen and Cafeteria Areas)

A variety of steps can be taken to effect more efficient use of energy in kitchen, cafeteria and other food-handling areas:

MINIMAL EXPENSE

√a. Turn off infrared food warmers when no food is being warmed.
√b. Inspect refrigeration condensers routinely to ensure that they have sufficient air circulation and that dust is cleaned off coils.
√c. Inspect and repair walk-in or reach-in refrigerated area doors without automatic closers or tight gaskets.
√d. Train employees in conservation of hot water. Supervise their performance and provide additional instruction and supervision as necessary.
√e. Avoid using fresh hot or warm water for dish scraping.
√f. Keep refrigeration coils free of frost build-up.
√g. Clean and maintain refrigeration on water chillers and cold drink dispensers.
√h. Reduce temperature or turn off frying tables and coffee urns during off-peak periods.
√i. Preheat ovens only for baked goods. Discourage chefs from preheating any sooner than necessary.
√j. Run the dishwasher only when it is filled.
√k. Cook with lids in place on pots and kettles. It can cut heat requirements in half.
√l. Thaw frozen foods in refrigerated compartments.
√m. Fans that cool workers should be directed so they do not cool cooking equipment.
√n. Consider using microwave ovens for thawing and fastfood preparation whenever they can serve to reduce power requirements.

3.4 Maintenance Modifications

The importance of good maintenance to a program of energy management cannot be overemphasized. Not only will effective maintenance help ensure efficient operation of equipment and systems, but it also will help prolong the usable life of equipment.

The maintenance guidelines presented herein all should be performed to at least bring systems up to efficiency. They also should be continued on a regularly scheduled basis depending on the nature of your system, frequency of operation, etc. Inspection of many of the items mentioned also will provide you with some idea about the effectiveness of the maintenance program now in effect and the condition of your equipment, some of which may need adjustment, repair or replacement.

Realize that these guidelines are general only. Whenever possible, the manufacturer of the equipment involved should be contacted to obtain pertinent literature describing the maintenance procedures suggested. Otherwise, those who regularly install such equipment, or who design heating and cooling systems, should be asked to prepare manuals or guidelines.

3.4.1 Refrigeration Equipment

Efficiency of refrigeration equipment can be improved considerably through following proper maintenance procedures. The following guidelines are suggested:

a. Circuit and Controls

MINIMAL EXPENSE

√i. Inspect moisture-liquid indicator on a regular basis. If the color of the refrigerant indicates "wet," it means there is moisture in the system. This is a particularly critical problem because it can cause improper operation or costly damage. A competent mechanic should be called in to perform necessary adjustments and repairs immediately. Also, if there are bubbles in the refrigerant flow as seen through the moisture-liquid indicator, it may indicate that the system is low in refrigerant. Call in a mechanic to add refrigerant if necessary and to inspect equipment for possible refrigerant leakage.

√ii. Use a leak detector to check for refrigerant and oil leaks around shaft seal, sight glasses, valve bonnets, flanges, flare connections, relief valve on the condenser assembly and at pipe joints to equipment, valves and instrumentation.

√iii. Inspect equipment for any visual changes such as oil spots on connections or on the floor under equipment.

√iv. Inspect the liquid line leaving the strainer. If it feels cooler than the liquid line entering the strainer, it is clogged. If it is very badly clogged, sweat or frost may be visible at the strainer outlet. Clean as required.

√v. Observe the noise made by the system. Any unusual sounds could indicate a problem. Determine cause and correct.

√vi. Establish what normal operating pressures and temperatures for the system should be. Check all gauges frequently to ensure that design conditions are being met. Increased system pressure may be due to dirty condensers, which will decrease system efficiency. High discharge temperatures often are caused by defective or broken compressor valves.

√vii. Inspect tension and alignment of all belts and adjust as necessary.

√viii. Where applicable, lubricate motor bearings and all moving parts according to manufacturer's recommendations.

√ix. Inspect insulation on suction and liquid lines.

b. Compressor

MINIMAL EXPENSE

√i. Look for unusual compressor operation such as continuous running or frequent stopping and starting, either of which may indicate inefficient operation. Determine the cause and if necessary, correct.

√ii. Observe the noise made by the compressor. If it seems to be excessively noisy, it may be a sign of a loose drive coupling or excessive vibration. Tighten compressor and motor on the base. If noise persists, call a competent mechanic.

√iii. Check all compressor joints for leakage. Seal as necessary.

√v. Inspect instrumentation frequently to ensure that operating oil pressure and temperature agree with manufacturer's specification.

c. Air-Cooled Condenser

MINIMAL EXPENSE

√i. Keep fan belt drive and motor properly aligned and lubricated.

√ii. Inspect refrigeration piping connections to the condenser coil for tightness. Repair all leaks.

√iii. Keep condenser coil face clean to permit proper air flow.

√iv. Determine if hot air is being bypassed from the fan outlet to the coil inlet. If so, correct the problem.

d. Evaporative Condenser

MINIMAL EXPENSE

√i. Inspect piping joints and seal all leaks.

√ii. Remove all dirt from the coil surface by washing to down with high velocity water jets or a nylon brush.

√iii. Inspect air inlet screen, spray nozzle or water distribution holes, and pump screen. Clean as necessary.

√iv. Use water treatment techniques if local water supply leaves surface deposits on the coil.

√v. Follow guidelines for fan and pump maintenance.

e. Watercooled Condenser

MINIMAL EXPENSE

i. Clean condenser shell and tubes by swabbing with a suitable brush and flushing out with clean water. Chemical cleaning also is possible, although it is suggested that a water treatment company be consulted first.

f. Cooling Towers

MINIMAL EXPENSE

√i. Perform chemical treatment to determine if solid concentrations are being maintained at an acceptable level.

√ii. Check overflow pipe clearance for proper operating water level.

√iii. Check fan by listening for any unusual noise or vibration. Inspect condition of V-belt. Align fan and motor as necessary.

√iv. Follow guidelines for fan maintenance.

√v. Keep the tower clean to minimize both air and water pressure drop.

√vi. Clean intake strainer.

√vii. Determine if there is air bypass from tower outlet back to inlet. If so, bypass may be reduced through addition of baffles or higher discharge stacks.

√viii. Inspect spray filled or distributed towers for proper nozzle performance. Clean nozzles as necessary.

√ix. Inspect gravity distributed tower for even water depth in distribution basins.

√x. Monitor effectiveness of any water treatment program which may be underway.

g. Chillers

MINIMAL EXPENSE

√i. Chillers must be kept clean. Inspect on a regular basis. Clean as necessary.

ii. Inspect for evidence of clogging. A qualified mechanic should be called in to service equipment in accordance with manufacturer's specifications.

iii. Keep water-side condenser tubing clean, and keep the refrigerant-side free of noncondensables. Noncondensables, tubefouling, dirty strainers, poor cooling tower performance, and poor water treatment can result in high condensing pressures.

iv. Consider installation of automatic tube cleaners to reduce condensing temperatures and to maintain low fouling factors. One of the automatic tube cleaners available features a cylindrical brush in each tube. The brush is periodically forced from one end of the condenser tube bundle to the other by reversing direction of water flow. Effective for maintaining condenser tubes, it can yield substantial energy savings, depending on the existing level of condenser tube-fouling.

h. Absorption equipment

MINIMAL EXPENSE

√i. Clean strainer and seal tank on a regular basis.

√ii. Lubricate flow valves on a regular basis.

√iii. Follow manufacturers instructions for proper maintenance.

i. Self-Contained Units. (Windows and through-the-wall units; heat pump, etc.)

MINIMAL EXPENSE

√i. Clean evaporator and condenser coils.

√ii. Keep air intake louvers, filters and controls clean.

√iii. Keep air flow from units unrestricted.

√iv. Caulk openings between unit and windows or wall frames.

√v. Check voltage. Full power voltage is essential for proper operation.

√vi. Follow applicable guidelines suggested for compressor, air-cooled condenser and fans.

3.4.2 Heating Equipment

There are numerous different kinds of heating systems installed in existing office buildings and retail stores. Certain common maintenance guidelines to improve efficiency of operation include the following:

a. Boilers (General)

MINIMAL EXPENSE

√i. Inspect boilers for scale deposits, accumulation of sediment or boiler compounds on water side surfaces. Rear portion of the boiler must be checked because it is the area most susceptible to formation of scale. (Scale reduces the efficiency of the boiler and possibly can lead to overheating of furnace, cracking of tube ends and other problems.

√ii. Fireside of the furnace and tubes must be inspected for deposits of soot, flyash and slag. Fireside refractory surface also must be observed. Soot on tubes decreases heat transfer and lowers efficiency. (If your boilder does not now have one, consider installation of thermometer in the vent outlet. It can save inspection time and often can prove to be more accurate than visual inspection alone.) If gas outlet temperature rises above normal, it can mean that tubes need cleaning. Evidence of heavy sooting in short periods could be a signal of too much fuel and not enough air. Adjustment of the air/fuel ratio is required to obtain clean burning fire.

√iii. Inspect door gaskets. Replace them if they do not provide a tight seal.

√iv. Keep a daily log of pressure, temperature and other data obtained from instrumentation. This is the best method available to determine the need for tube and nozzle cleaning, pressure or linkage adjustments, and related measures. Variations from normal can be spotted quickly, enabling immediate action to avoid serious trouble. On an oil-fired unit, indications of problems include an oil pressure drop, which may indicate a plugged strainer, faulty regulating valve, or an air leak in the suction line. An oil temperature drop can indicate temperature control malfunction or a fouled heating element. On a gas-fired unit, a drop in gas pressure can indicate a drop in the gas supply pressure or malfunctioning regulator.

√v. Note firing rate when log entries are made. Realize that even a sharp rise in stack temperature does not necessarily mean poor combustion or fouled waterside or fireside. During load change, stack temperatures can vary as much as 100°F in five minutes.

√vi. Inspect stacks. They should be free of haze. If not, it probably indicates that a burner adjustment is necessary.

√vii. Inspect linkages periodically for tightness. Adjust when slippage or jerky movements are observed.

√viii. Observe the fire when the unit shuts down. If the fire does not cut off immediately, it could indicate a faulty solenoid valve. Repair or replace as necessary.

√ix. Inspect nozzles or cup of oil-fired units on a regular basis. Clean as necessary.

√x. Check burner firing period. If it's improper, it could be a sign of faulty controls.

xi. Check boiler stack temperature. If it is too high (more than 150°F above steam or water temperature) clean tubes and adjust fuel burner.

√xii. Inspect all boiler insulation, refractory, brickwork, and boiler casing for hot spots and air leaks. Repair and seal as necessary.

√xiii. Replace all obsolete or little-used pressure vessels.

√xiv. Clean mineral or corrosion build-up on gas burners.

b. Boilers (Fuel Oil)

MINIMAL EXPENSE

√i. Check and repair oil leaks at pump glands, valves or relief valves.

√ii. Inspect oil line strainers. Replace if dirty.

√iii. Inspect oil heaters to ensure that oil temperatures are being maintained according to manufacturer's or oil supplier's recommendations.

c. Boilers (Coal-Fired)

MINIMAL EXPENSE

√i. Inspect coal-fired stokers, grates and controls for efficient operation. If ashes contain an excessive amount of unburned coal, it's probably a sign of inefficient operation.

d. Boilers (Electric)

MINIMAL EXPENSE

√i. Inspect electrical contacts and working parts of relays and maintain in good working order.

√ii. Check heater elements for cleanliness. Replace as necessary.

√iii. Check controls for proper operation. Adjust as necessary.

e. Central Furnaces, Make-Up Air Heaters and Unit Heaters

MINIMAL EXPENSE

√i. All heat exchanger surfaces should be kept clean. Check air-to-fuel ratio and adjust as necessary.

√ii. Inspect burner couplings and linkages.

√iii. Inspect casing for air leaks and seal as necessary.

√iv. Inspect insulation and repair or replace as necessary.

√v. Follow guidelines suggested for fan and motor maintenance.

f. Radiators, Convectors, Baseboard and Finned Tube Units

MINIMAL EXPENSE

i. Inspect for obstructions in front of the unit and remove whenever possible. Air movement in and out of convector unit must be unrestricted.

ii. Air will sometimes collect in the high points of hydronic units. It must be vented to enable hot water to circulate freely throughout the system. Otherwise, the units will short cycle (go on and off quickly), wasting fuel.

iii. Heat transfer surfaces of radiators, convectors, baseboard and finned-tube units must be kept clean for efficient operation.

g. Electric Heating

MINIMAL EXPENSE

√i. Keep heat transfer surfaces of all electric heating units clean and unobstructed.

√ii. Keep air movement in and out of the units unobstructed.

√iii. Inspect heating elements, controls and, as applicable, fans on a periodic basis to ensure proper functioning.

√iv. As appropriate, check reflectors on infrared heaters for proper beam direction and cleanliness.

√v. Determine if electric heating equipment is operating at rated voltage as necessary.

√vi. Check controls for proper operation.

3.4.3 Humidification and Dehumidification Equipment

To maintain peak operating efficiency, the following maintenance guidelines should be followed:

√a. Remove lint and dust periodically from air dampers, fan parts, spray chamber and diffuser, controls starter, and eliminator.

√b. Check equipment for carry-over. Carry-over may be maintained by adjusting eliminator seal gap, altering damper position, or changing air velocity.

√c. Follow guidelines suggested for "Fan and Motor Maintenance."

3.4.4 Air Handling Equipment

Proper maintenance of air handling equipment can significantly improve its efficiency. Proper maintenance guidelines include:

MINIMAL EXPENSE

√a. **Inspect ductwork for air leakage. Seal all leaks by taping or caulking.**
√b. **Inspect ductwork insulation. Repair or replace as necessary.**
√c. **Utilize ductwork access openings to check for any obstructions such as loose hanging insulation (in lined ducts), loose turning vanes and accessories, and closed fire dampers. Adjust, repair or replace as necessary.**
√d. **Inspect damper blades and linkages. Clean, oil and adjust them on a regular basis.**
√e. **Inspect air valves in dual duct mixing boxes to ensure full seating and minimum air leakage.**
√f. **Inspect mixing dampers for proper operation.**
√g. **Clean or replace air filters on a regular basis.**
√h. **Inspect air heating, cooling and dehumidification coils for cleaniness. Coils can be kept clean by using a mixture of detergent and water in a high pressure (500 psig) portable cleaning unit.**
√i. **Inspect for leakage around coils or out of the casing. Seal all leaks.**
√j. **Inspect all room air outlets and inlets (diffusers, registers and grilles). They should be kept clean and free of all dirt and obstructions. Clean and remove obstructions as necessary.**
√k. **Inspect air washers, and evaporative air cooling equipment for proper operation. Clean damper blades and linkages if so equipped. Inspect nozzles and clean as necessary.**
√l. **If electronic air cleaners are installed, check them regularly for excessive accumulations on the ionizing and grounding plate section. Replace filter media if necessary. Follow manufacturer's written instructions whenever adjustment or maintenance is required.**
√m. **Inspect humidifier/dehumidifier air dampers, fan parts, spray chamber, diffuser, controls, strainer and eliminator. All must be kept free of dirt, lint and other foreign particles. Clean eliminator wheel by directing a high pressure stream of water between blades.**
√n. **Adjust all VAV (variable air volume) boxes so they operate precisely. This will prevent overheating or overcooling, both of which waste energy.**
√o. **Follow guidelines suggested for fan maintenance.**

3.4.5 Prime Movers — Motors, Engines Turbines

Proper maintenance of motors, engines and turbines can greatly improve operational efficiency and so eliminate energy consumption. The following maintenance guidelines are suggested:

a. Motors

√i. **Check alignment of motor to equipment driven. Align and tighten as necessary.**
√ii. Check for loose connections and bad contacts on a regular basis. Correct as necessary.
√iii. Keep motors clean.
√iv. Eliminate excessive vibrations.
√v. Lubricate motor and drive bearings on a regular basis. This will help reduce friction and excessive torque which can result in overheating and power losses.
√vi. Replace worn bearings.
√vii. Tighten belts and pulleys to eliminate excessive losses.
√viii. Check for overheating. It could be an indication of a functional problem or lack of adequate ventilation.
√ix. Balance three-phase power sources to motors. An imbalance can create inefficient motor operation and use of more energy.
√x. Check for overvoltage or low voltage condition on motors. Correct as necessary.

b. Engines

√i. Follow manufacturers recommended maintenance procedure.
√ii. Check fuel consumption and compare with design fuel consumption.
√iii. Record and check cooling water temperatures daily. If cooling water temperatures exceed manufacturers recommendations, check temperature controls and correct as necessary.

c. Turbines

√i. Follow manufacturers recommended maintenance procedures.
√ii. Daily record steam pressure and check speed.
√iii. Regularly check oil level, packing leakage, governor and throttle valve operation.
√iv. Record and check bearing temperatures.
√v. Record and check oil cooler temperatures.
√vi. Weekly check vibrations.

3.4.6 Fans and Pumps

Proper maintenance of fans and pumps can greatly improve operational efficiency and so eliminate unnecessary energy consumption. The following maintenance guidelines are suggested:

a. Fans

MINIMAL EXPENSE

√i. Check for excessive noise and vibration. Determine cause and correct as necessary.
√ii. Keep fan blades clean.
√iii. Inspect and lubricate bearings regularly.
√iv. Inspect drive belts. Adjust or replace as necessary to ensure proper operation. Proper tensioning of belts is critical.
√v. Inspect inlet and discharge screens on fans. They should be kept free of dirt and debris at all times.

b. Pumps

MINIMAL EXPENSE

√i. Check for packing wear which can cause excessive leakage. Repack to avoid excessive water wastage and shaft erosion.

√ii. Inspect bearings and drive belts for wear and binding. Adjust, repair or replace as necessary.

3.4.7 Hot and Chilled Water Piping

Proper maintenance of hot and chilled water piping will improve the efficiency of the piping system. Guidelines for effective maintenance of piping systems include:

MINIMAL EXPENSE

√a. Inspect all controls. Test them for proper operation. Adjust, repair or replace as necessary. Also check for leakage at joints.

√b. Check flow measurement instrumentation for accuracy. Adjust, repair or replace as necessary.

√c. Inspect insulation of hot and chilled water pipes. Repair or replace as necessary. Be certain to replace any insulation damaged by water. Determine source of water leakage and correct.

√d. Inspect strainers. Clean regularly.

√e. Inspect heating and cooling heat exchangers. Large temperature differences may be an indication of air binding, clogged strainers or excessive amounts of scale. Determine cause of condition and correct.

√f. Inspect vents and remove all clogs. Clogged vents retard efficient air elimination and reduce efficiency of the sytem.

3.4.8 Steam Piping

Proper maintenance of steam piping will, among other things, prevent unnecessary wastage of steam. Effective maintenance procedures include:

MINIMAL EXPENSE

√a. Inspect insulation of all mains, risers and branches, economizers and condensate receiver tanks. Repair or replace as necessary.

√b. Check automatic temperature-control system and related control valves and accessory equipment to ensure that they are regulating the system properly in the various zones—in terms of building heating needs, not system capacity.

√c. Inspect zone shut-off valves. All should be operable so steam going into unoccupied spaces can be shut off.

√d. Inspect steam traps. Their failure to operate correctly can have a significant impact on the overall efficiency and energy consumption of the system. Several different tests can be utilized to determine operations.

 √i. Listen to the trap to determine if it is opening and closing when it should be.

 √ii. Feel the pipe on the downstream side of the trap. It if is excessively hot, the trap probably is passing steam. This can be caused by dirt in the trap, valve off stem, excessive steam pressure, or worn trap parts (especially valve and seats). If it is moderately hot — as hot as a hot water pipe, for example — it probably is passing condensate, which it should do. If it's cold, the trap is not working at all.

 √iii. Check back pressure on downstream side.

 √v. Measure temperature of return lines with a surface pyrometer. Measure temperature drop across the trap. Lack of drop indicates steam blow-through. Excessive drop indicates that the trap is not passing condensate. Adjust, repair or replace all faulty traps.

√e. Inspect all pressure-reducing and regulating valves and related equipment. Adjust, repair or replace as necessary.

√f. Inspect condensate tank vents. Plumes of steam are an indication of one or more defective traps. Determine which traps are defective and adjust, repair or replace as necessary.

√g. Check accuracy of recording pressure gauges and thermometers.

√h. Inspect pump for satisfactory operation, looking particularly for leakage at the packing glands.

√i. Correct sluggish or uneven circulation of steam. It usually is caused by inadequate drainage, improper venting, inadequate piping, or faulty traps and other accessory equipment.

√j. Correct any excessive noise which may occur in the system to provide more efficient heating and to prevent fittings from being ruptured by water hammer.

√k. Check vacuum return system for leaks. Air drawn into the system causes unneccessary pump operation, induces corrosion and causes the entire system to be less efficient.

3.4.9 Pneumatic Air Compressor for Controls

Efficiency of pneumatic air compressors can be improved by following these guidelines:

MINIMAL EXPENSE

√a. Inspect all connections for air leaks using a soap solution. Seal as necessary.

√b. Note operation. If compressor seems to run excessively, it could be a sign of pressure loss at the controls or somewhere in the piping system. Determine cause and correct.

√c. Inspect air pressure in supply tank and pressure regulator adjustment in supply line for proper limits.

√d. Check belt tension and alignment.

√e. Inspect air compressor intake filter pads and clean or replace as necessary.

√f. Lubricate electric motor bearings according to manufacturer's recommendations.

3.5 Central Plant Modifications

Central plant modifications worthy of discussion in this publication relate primarily to boiler modifications. Although numerous chiller plant modifications also are possible, most require significant expense and, except in certain major installations, are economically feasible only to replace a system which has reached the end of its useful life.

Most of the following changes require significant expense. In most cases a feasibility study will be required prior to undertaking a modification.

a. Install Boiler Stack Economizer

A boiler stack economizer is a simple heat exchanger placed inside the exhaust stack which uses boiler feed water as the transfer medium. Heat captured from the exhaust gases increases the temperature of the feed water distributed to the boiler. In past years this technique was limited to systems using low or nonsulphur content fuels to avoid build-up caused when the economizer cooled exhaust gases to the sulphur dew point. Newer systems overcome this problem by incorporating a solid-state control which keeps stack temperatures above the dew point by controlling the volume of feed water passing through the transfer coils.

b. Preheat Oil to Increase Efficiency

Preheating oil can increase efficiency by as much as 3% depending on the particular constituents of the oil involved. Heat required to attain complete atomization can be obtained through use of reclamation procedures discussed in 11.1, below. Heating oil beyond 135°F for #4 oil, 185°F for #5, or 210°F for #6 will increase efficiency even more, except care must be taken not to overheat, which could cause vapor locking and flame-out. Recommendations of the oil supplier should be followed.

c. Preheat Combustion Air To Increase Boiler Efficiency

Preheating primary and secondary air increase boiler efficiency by reducing the cooling effect when the air enters the combustion chamber and by promoting more intimate mixing of fuel and air. It is estimated that each 100°F increase in combustion air temperature increases boiler efficiency by 2%. Combustion air can be preheated up to 600°F for prevalent fuels and up to 350°F for stoker-fired coal oil and gas. The maximum temperature permissable is determined by the type of construction involved and the materials of the firing equipment. Several sources of heat are available to perform preheating. As an example, ambient air in most boiler rooms is heated incidently by boiler and pipe surfaces and collects below the ceiling. This air can be utilized directly as preheated combustion air by ducting it down to the firing level and directing it into the primary and secondary air intakes. Other methods available, discussed under Section 11.1 of this chapter involve recovering waste heat from boiler stacks, consensate, blowdown hot wells, and other sources. Manufacturer's recommendations should be followed in all cases.

d. Reduce Blowdown Losses

Blowing down a boiler has two purposes: (1) to maintain a low concentration of dissolved and suspended solids in the boiler water, and (2) to remove sludge in the boiler to avoid priming and carryover. There are two principal types of blowdown: intermittent manual blowdown and continuous blowdown. Manual blowdown (or sludge blowdown) is necessary whether or not continuous blowdown is installed, with frequency depending on the amount of solids in the boiler makeup water and the type of water treatment used. Continuous blowdown results in a steady energy drain because makeup water must be heated. In either case, blowdown energy losses can be minimized by installing automatic blowdown control and heat recovery systems. Automatic blowdown controls monitor the conductivity and PH of the boiler water periodically and blowdown the boiler only when required to maintain acceptable water quality. Further savings can be realized if the blowdown water is piped through a heat exchanger or a flash tank with a heat exchanger. In this way, for example, heat from the boiler blowdown flash tank can be used to feed reheating feed water heaters.

e. Isolate Off-Line Boilers

Light heating loads on a multiple boiler installation are often met by one boiler on line with the remaining boilers idling on stand-by. Idling boilers consume energy to meet stand-by losses. In many cases these losses are increased by a continuous induced flow of air through the idling boilers, and up the chimney. Unless a boiler is about to be used to meet an expected increase in load, it should be secured and isolated from the heating system (by closing valves) and from the stack and chimney (by closing dampers). A large boiler can be fitted with by-pass valves and regulating orifice to allow the minimum flow required to keep it warm and avoid thermal stress when it is brought online again. If a boiler waterside is isolated, it is important to prevent back flow of cold air through the stack which could cause the boiler to freeze.

f. Replace Boilers at or Near End of Useful Life

A boiler at or near the end of its useful life should be replaced by a modern version which is matched to current and projected needs of the installation involved. In most cases new boilers on the market can obtain 80% efficiency. Even more efficiency can be gained by specifying multiple boilers and/or air-atomizing burners as appropriate. Replacement burners should be selected on the basis of long-term cost rather than first cost. Increased cost of fuel, labor and materials should be considered in developing long-term cost projections. Also consider installation of a dual-fuel system to avoid problems in the event of any shortages or curtailments.

g. Replace Existing Boilers with Modular Boilers

Most boilers achieve maximum efficiency only when running at their rated output. In most cases, however, full boiler capacity is seldom required because heat load is 60% less than full load 90% of the time. As a result, large capacity boilers in single units operate intermittently for the major part of the heating season. Although hi-low firing capabilities may reduce cycling, the boilers can only reach their design efficiency for short periods resulting in low seasonal efficiencies. A modular boiler system comprising two or more small capacity boiler units will increase seasonal efficiency. Each module is fired at 100% of its capacity only when required. Fluctuations of load are met by firing more or less boilers. Each small capacity unit has low thermal inertia (providing rapid resonse and low heat-up and cool-down losses) and either will be running at maximum efficiency or will be turned off. In a typical installation where single unit large capacity boilers are replaced by modular boilers, boiler seasonal efficiency may be improved from 68% to 75%. This represents a 9% savings of present fuel consumption. Use of the modular approach is particularly worthwhile in cases where the present boiler plant is at or near the end of its useful life. Replacement modular boilers should be sized to meet the reduced heating load resulting from implementation of other measures.

h. Convert from Steam-Atomizing Burners to Air-Atomizing Burners

Steam-atomizing burners consume at least 1.5% of total capacity to atomize the fuel oil. By contrast, air-atomizing burners rely on a simple electrically driven air compressor which costs far less to operate. Accordingly, when an existing steam-atomizing burner is at or near the end of its useful life, an air-atomizing replacement should be considered. In certain cases the savings to be obtained from an air-atomizing burner will warrant its installation prior to the scheduled replacement of the existing system.

i. Isolate Off-Line Chillers

Light cooling loads on a multiple chiller installation often are met by circulating chilled water through all chillers even though only one chiller is operating. This wastes pump energy by maintaining an unnecessarily high water flow rate through the system. It also forces the remaining on-line chiller to produce chilled water at low temperatures to offset the mixing effect of the bypass to meet the desired supply temperature and so causes the on-line chiller to operate at low evaporator temperatures (COP drops). Install isolating valves so off-line chillers can be isolated under light loads, thereby reducing chilled water flow rate. If multiple chilled water pumps are installed, shut off those that are unneeded. If multiple chilled water pumps are not installed, consider installing additional pumps or a multi-speed drive on the present pump.

3.6 General Systems Modifications

The only way to determine the efficiency of your heating/cooling system is to have the entire system tested and balanced in accord with the latest current procedures outlined by the American Society of Heating, Refrigerating and Air-Conditioning Engineers. The extent of testing required and its cost will depend primarily on the type of system involved (and therefore no cost categorization has been included).

In all cases the survey itself should be conducted by a qualified individual who has a thorough knowledge of heating and cooling systems, experience in testing and balancing, and the instrumentation and manpower required to collect and analyze the necessary data.

The most prevalent types of systems and steps which can be taken to make them more energy efficient are discussed as follows:

3.6.1 Terminal Reheat System

The terminal reheat system essentially is a modification of a single-zone system which provides a high degree of temperature and humidity control. The central heating/cooling unit provides air at a given temperature to all zones served by the system. Secondary terminal heaters then reheat air to a temperature compatible with the load requirements of the specific space involved. Obviously, the high degree of control provided by this system requires an excessive amount of energy. Several methods for making the system more efficient include:

a. Reduce the supply air quantity.
b. De-energize or shut off reheat coils and raise the chilled water supply air temperature in summer months in increments of 3°F to determine the highest supply temperature which will maintain satisfactory room conditions. Temperatures which some commercial buildings have found suitable range from 60° to 70°F.
c. Adjust outside air, return air and mixed air damper controls in winter to raise supply air temperature to a level between 64° and 70°F, depending on the conditions in the area served by the system.
d. If close temperature and humidity control must be maintained for equipment purposes, lower water temperature and reduce flow to reheat coils. This still will permit control, but will limit the system's heating capabilities somewhat.
e. If close temperature and humidity control are not required, convert the system to variable volume by adding variable volume valves and eliminating terminal heaters.

3.6.2 Dual-Duct System

The central unit of a dual-duct system provides both heated and cooled air, each at a constant temperature. Each space is served by two ducts, one carrying hot air, the other carrying cold air. The ducts feed into a mixing box in each space which, by means of dampers, mixes the hot and cold air to achieve that air temperature required to meet load conditions in the space or zone involved. Methods for improving the energy consumption characteristics of this system include:

a. Lower hot deck temperature and raise cold deck temperature.
b. Reduce air flow to all boxes to minimally acceptable level.
c. When no cooling loads are present, close off cold ducts and shut down the cooling system. Reset hot deck according to heating loads and operate as a single duct system. When no heating loads are present, follow the same procedure for heating ducts and hot deck. It should be noted that operating a dual-duct system as a single duct system reduces air flow, resulting in creased energy savings through lowered fan speed requirements.
d. Consider converting to variable volume system when energy and economic analysis to do so is favorable.

3.6.3 Multizone System

A multizone system heats and cools several zones—each with different load requirements—from a single, central unit. A thermostat in each zone controls dampers at the unit which mix the hot and cold air to meet the varying load requirements of the zone involved. Steps which can be taken to improve energy efficiency of multizone systems include:

a. Reduce hot deck temperatures and increase cold deck temperatures. While this will lower energy consumption, it also will reduce the system's heating and cooling capabilities as compared to current capabilities.
b. Consider installing demand reset controls which will regulate hot and cold deck temperatures according to demand. When properly installed, and with all hot deck or cold deck dampers partially closed, the control will reduce hot and raise cold deck temperature progressively until one or more zone dampers is fully open.
c. Consider converting systems serving interior zones to variable volume. Conversion is performed by blanking off the hot deck, removing or disconnecting mixing dampers, and adding low pressure variable volume terminals and pressure bypass.

3.6.4 Induction Systems

Induction systems comprise an air handling unit which supplies heated or cooled primary air at high pressure to induction units located on the outside walls of each space served. The high pressure primary air is discharged within the unit through nozzles inducing room air through a cooling or heating coil in the unit. The resultant mixture of primary air and induced air is discharged to the room at a temperature dependent upon the cooling and heating load of the space. Methods for conserving energy consumed by this system include:

a. Set primary air volume to original design values when adjusting and balancing work is performed.
b. Inspect nozzles. If metal nozzles, common on most older models, are installed, determine if the orifices have become enlarged from years of cleaning. If so, chances are that the volume/pressure relationship of the system has been altered. As a result, the present volume of primary air and the appropriate nozzle pressure required must be determined. Once done, rebalance the primary air system to the new nozzle pressures and adjust individual induction units to maintain airflow temperature. Also, inspect nozzles for cleanliness. Clogged nozzles provide higher resistance to air flow, thus wasting energy.
c. Set induction heating and cooling schedules to minimally acceptable levels.
d. Reschedule the temperature of the heating water and the cooling water according to the load. Avoid simultaneous heating or cooling in any one zone.
e. Reduce secondary water flow during minimum heating and cooling periods by pump throttling or, for dual-pump systems, by operating one pump only.
f. Consider manual setting of primary air temperature for heating, instead of automatic reset by outdoor or solar controllers.
g. For operation during unoccupied hours in the heating season, shut down primary air fans, raise the hot water temperature and operate the induction units as gravity convectors.

3.6.5 Variable Air Volume System

A variable volume system provides heated or cooled air at a constant temperature to all zones served. VAV boxes located in each zone or in each space adjust the quanitity of air reaching each zone or space depending on its load requirements. Methods for conserving energy consumed by this system include:

a. Reduce the volume of air handled by the system to that point which is minimally satisfactory.
b. Lower hot water temperature and raise chilled water temperature in accordance with space requirements.
c. Raise air supply temperature to that point which will result in the VAV box serving the space with the most extreme load being fully open.
d. Consider installing static pressure controls for more effective regulation of pressure bypass (inlet) dampers.
e. Consider installing fan inlet damper control systems if none now exist.

3.6.6 Constant Air Volume System

Most constant volume systems either are part of another system — typically dual duct system — or serve to provide precise air supply at a constant volume. Opportunities for conserving energy consumed by such systems include:

a. Determine the minimum amount of airflow which is satisfactory and reset the constant volume device accordingly.
b. Investigate the possibility of converting the system to variable (step controlled) constant volume operation by adding the necessary controls.

3.6.7 Single Zone System

A zone is an area or group of areas in a building which experiences similar amounts of heat gain and heat loss. A single zone system is one which provides heating and cooling to one zone controlled by the zone thermostat. The unit may be installed within or remote from the space it serves, either with or without air distribution ductwork.

a. Implementing energy conservation measures which reduce the heating and/or cooling of air handled by the HVAC system results in reduced fan power input requirements. Fan brake horsepower varies directly with the cube of air volume. Thus, for example, a 10% reduction in air volume will permit a reduction in fan power input by about 27% of original. This modification will limit the degree to which the zone serviced can be heated or cooled as compared to current capabilities.
b. Raise supply air temperatures during the cooling season and reduce them during the heating season. This procedure reduces the amount of heating and cooling which a system must provide, but, as with air volume reduction, limits heating and cooling capabilities.
c. Avoid simultaneous heating and cooling except as required for humidity control in critical areas.
d. Consider converting single zone, single duct systems to variable volume by adding variable volume boxes at each branch. Fan volume should preferably be controlled according to demand either by installing inlet guide vanes or by installing a variable speed motor or two speed.
e. Use the cooling coil for both heating and cooling by modifying the piping. This will enable removal of the

heating coil, which provides energy savings in two ways. First, air flow resistance of the entire system is reduced so that air volume requirements can be met by lowered fan speeds. Second, system heat losses are reduced because surface area of cooling coils is much larger than that of heating coils, thus enabling lower water temperature requirements. Heating coil removal is not recommended if humidity control is critical in the zone serviced and alternative humidity control measures will not suffice.

3.6.8 Fan Coil System

A fan coil system usually comprises several fan coil units, each of which consists of a fan and a heating and/or cooling coil. The individual units can be located either in or remote from the space or zone being served. Guidelines for reducing energy consumption of such systems include:

a. Reduce air flow to minimally satisfactory levels.
b. Balance water flows to minimally satisfactory levels.
c. When heating and cooling loads are minimal, shut off fans so enabling the coil to act as a convector.
d. Consider installing interlocks between the heating and cooling systems of each unit to prevent simultaneous heating and cooling.
e. Consider face zoning two-pipe systems from four-pipe central system to avoid changeover losses.

3.6.9 Self-Contained Systems

Energy consumption of self-contained systems, such as rooftop, window, through-the-wall and other heating and/or cooling units, can be modified as follows:

a. If multiple units are involved, consider installation of centralized automatic shut-off and manual override controls.
b. If units are relatively old, consider replacing them with more efficient air-to-air heat pumps or similar units having a higher equivalent efficiency rating.

3.6.10 General

Regardless of the type system currently installed, consider adding to the system portable electric baseboard, unit, infrared or other types of supplemental heating units to overcome cold conditions which cannot be overcome by the current system, or to heat remote or occasionally-used areas which otherwise could be heated only through activation of all or substantially all of a central system.

3.7 Distribution Systems Modifications

A distribution system comprises the equipment and materials necessary for conveying the heating and cooling media — water, steam or air. Most versions of the nine general systems previously discussed employ one or more of the following distribution systems.

3.7.1 Hydronic Systems

Hydronic systems are those which utilize water for transferring heating and cooling. Some of the modifications which can be made to these systems are as follows:

MINIMAL EXPENSE

a. Install insulation on all hot and chilled water pipes, fittings and valves passing through unconditioned spaces to minimize heat losses and heat gains.
b. Replace fine mesh strainer baskets with ones having the largest practical openings to reduce pressure losses.
c. Remove orifice plates not regularly used for flow measurement.
d. Balance hydronic systems to attain minimally satisfactory temperature and water flow.
e. Trim impeller to actual size required on pump curve after terminal unit flows are reduced to the minimum. This will enable reductions of power requirements of actual load.
f. Install flow measurement instrumentation where none now exists. (Factory-assembled pipe-mounted instrumentation can easily be cut into the system.)
g. Check sizing of valves, filters and pipe sections. All those which are undersized should be replaced.
h. Check all pipe fittings. Replace those which are inefficient.
i. Consider adding a parallel small-GPM pump to handle heating load for dual temperature changeover systems.
j. Consider adding a variable speed drive. Although this will conserve energy, it will limit the pump's ability to handle flow to the farthest terminal units.

3.7.2 Steam Systems

Steam systems are those which utilize steam as a heat source. The steam can be provided either by an on-site boilder or by district steam. Methods for modifying the steam distribution system are as follows:

MINIMAL EXPENSE

a. Install insulation on all mains, riser, and branches, economizers, water heaters, and condensate receiver tanks where none now exists.
b. Add additional shut-off valves for more efficient zone control.
c. Install recorder pressure gauges and thermometers where none now exists to enable continual monitoring of the system.
d. Modify equipment as necessary to recover heat now going to the sewer. Such reclaimed heat from condensate can be used for boiler feedwater heating; to heat a portion of the building; to preheat water being supplied to the domestic hot water heater or be returned to the boilders.

3.7.3 Air Distribution Systems

Air distribution systems are those which use air for heating and/or cooling. Ways in which air distribution systems can be modified to effect energy conservation are:

MINIMAL EXPENSE

a. Test, adjust and balance entire air distribution system in accordance with methodology suggested in the latest ASHRAE Handbook and Product Guide.

b. Insulate all ductwork carrying conditioned air through unoccupied spaces with at least 1½" of fibrous insulation or its thermal equivalent.

c. Reduce system resistence to air flow to a minimum by replacing those duct sections and fittings which impose unnecessary resistance on the system; replacing dirty filters with adequately sized filter media which have high efficiency and low air flow resistance; removal of unnecessary dampers and other obstructions from ductwork and replacing high resistance inlets and outlets with modern grilles and diffusers providing low resistance.

d. Reduce fan power input equipments by reducing air volume. Whenever heating and cooling loads are reduced, fan air volume reductions should be implemented to reduce fan energy consumption. Air volume can be reduced by changing the speed of rotation as follows:

- Where motor sheave is adjustable, open the "v" to reduce its effective diameter and adjust motor position or change belts to maintain proper tension.
- Change motor sheave if no further adjustment is possible.
- If motors are variable speed, set controller for reduced speed.

Following air volume reduction, determine resulting load on the fan motor. If one full load on the motor is less than 60% of the nameplate rating, consider changing the motor for a smaller one.

SIGNIFICANT EXPENSE

e. Relocate air outlets or rearrange ductwork so that air entering the space does not first come into contact with hot surfaces.

3.8 Control Adjustment and Modifications

The controls originally installed in your building probably were designed more in light of initial costs than they were for their ability to conserve energy. In addition, just five years' use without adequate maintenance — which seldom is performed — can cause controls to go out of calibration, becoming even less sensitive. A program of control adjustment and modification should consider the following guidelines:

MINIMAL EXPENSE

a. Adjust controls at the time of testing, adjusting and balancing of all heating and cooling systems.

b. Check operation of entire heating/cooling control system, including control valves and dampers. Correct all improper operations.

c. Check control system for instrument calibration and set point, actuator travel and action, and proper sequence of operation.

d. Inspect and calibrate pressure controls on dual duct system to obtain minimum static pressure during low demand and less leakage.

e. Adjust controls where applicable to prevent simultaneous operation of heating and cooling systems to achieve desired temperature.

f. Add controls to enable up to 100% shut-down of air and water to unoccupied space.

g. Inspect locations of thermostats. Relocate if they currently are positioned near outside walls, in areas that are seldom used, or if they are subject to outside drafts.

h. Consider installation of key-lock plastic covers over thermostats to prevent building occupants from adjusting settings.

i. Consider replacing pilots of gas burning equipment with electric ignition devices.

j. Limit the use of reheat to areas where humidity control is needed because of equipment needs.

k. Install thermostats for control of all heating equipment where none currently exist.

l. Consider installation of night set-back and morning start-up controls which enable you to schedule heating and cooling operations for each zone on the basis of occupancy patterns. Such controls easily can save from 10% to 30% on fuel consumption. A consultant should be utilized to determine when start-up should take place to ensure comfort for occupants when they arrive for work.

m. Consider installation of program clocks and manual overcall timers in control circuits to enable savings through scheduled operation of fans, refrigeration equipment, heating equipment and so on. Additional economies may result from decreased costs of labor and maintenance.

n. If a chilled water central plant currently is used to provide cooling, determine if the chiller plant can be shut down when outdoor temperature is below 50°. Add control valves and controllers which allow chilled water to flow from chillers to condenser water cooling tower to enable "free cooling." Similar controls must be added to condenser water system.

o. Adjust automatic timers or add time clocks to deactivate heating and cooling systems during evenings, weekends, holidays and other periods when the building is unoccupied.

p. Consider adding an automatic draft damper control to reduce heat loss through breaching when the gas or oil burner is not in operation.

q. Consider installation of automatic door closers on swinging doors leading to the exterior. Also consider such devices for garage and loading platform door operations.

r. Consider adding time clocks on self-contained heating and cooling units for automatic shut-off.

s. Consider adding a step-controller to electric heating systems with resistance elements to permit staging, resulting in more effective heat control and demand management.

t. Consider installation of a dead band control system to control the HVAC system on the basis of room temperature alone. It works as follows:

First, a dead band is established. This is a range of temperatures, such as 70° to 75°F, for which the HVAC system provides ventilation only, without heating or cooling.

Second, the throttling range (range of acceptable room air temperature) is extended, from the 1.5°F typically found in existing HVAC systems. As a result, the thermostat calls for more heating or cooling gradually, as the temperature floats further away from the dead band. At the limits of the throttling range, 68°F and 78°F for example, the HVAC system is working "full throttle" to return the space to a more comfortable temperature.

Third, a space demand reset is provided to reset the temperature of the air being supplied to heat or cool the space, on the basis of space temperature, as opposed to outside air temperature or a fixed setting. Accordingly, a space temperature of 68°F might call for 90°F supply air; at 70°F, only 75°F supply air would be required. About 25-40% of all zones are used as sample zones to provide space demand reset feedback for control of the central air handling unit heating and cooling coils. The controls of the remaining zones are also modified, but they do not affect the control of the central air handling unit's heating or cooling coils.

If the existing HVAC system has economizer controls, a dead band control system causes economizer dampers to be controlled by room air temperature at a given outside air temperature. In this way, the system makes maximum use of outside air. Enthalpy control can be added where humidity conditions warrant.

u. Consider use of microprocessor-based energy management control (EMC) systems. These are available as single-function devices, multi-function devices, or comprehensive automated building control systems which integrate control and monitoring of most energized systems. Although the expense associated with these devices can be substantial, the savings can be so significant that paybacks of less than one year can be achieved. EMC devices are discussed in detail in Section 11.2.

4. TRANSMISSION

Transmission losses generally can be reduced either through modification of glazing characteristics or addition of insulation.

4.1 Glazing

In all cases, preferential treatment should be given to those windows most exposed to direct sunlight or high levels of reflected sunlight.

MINIMAL EXPENSE

√a. Inspect condition of indoor shading devices such as drapes and blinds which can reduce heat gain as much as 50%. Keep indoor shading devices clean and in good repair.

√b. During the heating season, close all interior shading devices before leaving space to reduce night-time heat losses.

c. Use opaque or translucent insulating materials to block off and thermally seal all unused windows.

SIGNIFICANT EXPENSE

d. Consider adding reflective and/or heat-absorbing film to glazing to reduce solar heat gains by as much as 80%. Do be aware that such films will reduce substantially the benefits of natural lighting.

e. Consider adding reflective materials to the window side of draperies to reflect solar heat when draperies are drawn.

f. Install indoor shading devices where none now exist, even if exterior shading devices are used. They should be light-colored and opaque.

g. Consider installation of outdoor shading devices, such as sunshades, which reflect solar heat before it has a chance to enter the building, and which dissipate heat outdoors rather than indoors. Adjustable sunshades enable entrance of warming rays during the heating season.

h. Consider installation of storm windows if practical.

i. Consider reglazing with double or triple-glazing, or with heat absorbing and/or reflective glazing materials.

4.2 Insulation

It is advised strongly that expert technical assistance be obtained before undertaking any insulating to help ensure that the proper type and correct amount are installed, that cost effectiveness will result, and that any potential problems — such as moisture condensation — can be avoided.

MINIMAL EXPENSE

a. Where roof insulation is not practical, consider insulating the top floor ceiling. This can be done easily with blow insulation. In most cases, ceiling insulation also will require a vapor barrier placed on the warm side of the ceiling — if not integral with the insulation — to prevent structural damage caused by rot, corrosion or expansion of freezing water.

b. If remodeling or modernization is contemplated, consider adding insulation to all exterior walls as well as those which separate conditioned and nonconditioned spaces. Refer to ASHRAE Standard 90-75 for insulation guidelines.

c. Add or improve insulation under floors over garages or other conditioned areas. Refer to ASHRAE Standard 90-75 for insulation guidelines.

SIGNIFICANT EXPENSE

d. Consider adding roof deck insulation, especially if your building is 20 years old or older. Assuming that the roof/ceiling sandwich is not used as a return air plenum, a thermal transmission value (U — value) of 0.08-0.10 Btu/hr. sq. ft. °F is considered to be an attainable goal through roof/ceiling sandwich.

5. LIGHTING

Because the lighting systems of many existing buildings were designed within the restrictions of initial cost economies, without knowledge about final space use and subdivision, and without benefit of relatively recent developments and research findings in the field, there exists significant potential for lighting system modification. These modifications can reduce substantially the energy consumed by the lighting system (and associated costs) while still providing building occupants with the quality and quantity of illumination required to perform their various tasks and functions.

Before undertaking any change, you must recognize that a lighting system is just that — a system. Its many elements all are interrelated with one another, just as the lighting system itself is interrelated with other systems in the building. While energy can be conserved by properly removing lamps and luminaires, realize that such action should be taken only after the entire system has been analyzed and all options evaluated. While conservation of energy is important, it must be achieved in a manner consistent with other requirements, including those of productivity and visual comfort; aesthetics; and federal, state and local codes and ordinances. Moreover, it is especially important to recognize that major alterations to a lighting system can have a significant impact on heating and cooling systems, most of which were designed to consider the amount of heat given off by the lighting system as originally designed. For these reasons, it is suggested strongly that competent technical assistance be obtained before any significant modifications are made and that modifications be made only in full light of the building's illumination needs, the lighting system which currently exists, and the many different options which can be utilized.

The following discussion highlights many of the actions which should or can be taken to implement an effective program of lighting energy management.

5.1 Modify Usage Patterns

An excellent initial step for a program of lighting management is to modify usage patterns based on factors identified during the energy audit. It should be noted that steps such as developing an effective lighting usage program have to be updated and modified as changes are made to the lighting system but, for the most part, such modifications should be relatively simple once the initial steps have been undertaken.

MINIMAL EXPENSE

√a. Establish and effective lighting usage program: a planned program to turn lights on when and where they are needed. The major advantages of such programs are that they can be tailored to the individual characteristics of the space and needs of its occupants, implemented relatively inexpensively, and implemented very quickly. The key element of a lighting usage program is a lighting schedule related to occupant usage patterns. Personnel should be assigned, trained and made responsible for the efficient utilization of lighting by means of established schedules for the control of lighting.

Define the exact nature of occupancy for each period of time. Determine the amount of lighting needed for safety and security purposes. Provide detailed instructions for system operation to responsible employees by means of charts, posting and/or color coding of switches. Train the responsible employees to assure understanding and compliance with the procedures.

For example, significant amounts of energy (and cost) can be conserved in buildings by means of lighting schedules requiring reduced lighting for daytime unoccupied (Saturdays, Sundays, and holidays), nightime unoccupied and maintenance periods (low lighting levels).

The following two options should be considered part of the overall program:

- Campaign for better utilization by using letters, memos, signs and personal contact to encourage occupants — especially custodial personnel — to use lighting only when it is needed, to use only the amount of lighting required, and to turn off lights whenever they are not being used.
- Post a small sign or chart near each switch which identifies which lights are controlled by the switch. This enables the user to be more selective while also reducing trial-and-error which can consume significant amounts of energy as banks of lights are quickly activated and deactivated.

Note that lighting systems can be controlled automatically, by independent time clocks, by time-clock elements of other control systems or by centralized lighting system controllers developed with microprocessor technology, as discussed in Section 11.2. However, the use of such systems cannot completely supplant the need for personnel cooperation; effective manual control still is required for maximum benefit.

5.2 Work Station Modifications

Work stations can be relocated to take maximum advantage of the lighting system which exists or to supplement or enable changes to other elements of the system. Typical modifications to work station locations are as follows:

MINIMAL EXPENSE

√a. Move desks and other work surfaces to a position and orientation that will use installed luminaires to their greatest advantage (instead of moving luminaires).

√b. To the extent permitted by productivity requirements and related concerns, group tasks which require approximately the same levels of illumination. This may reduce the number of areas requiring higher illumination levels and provide an opportunity to reduce the total amount of lighting needed.

√c. Relocate work stations requiring the highest illumination level to areas near windows. (Note: Recognize that utilization of natural lighting will affect heat gain, therefore requiring that the heat gain/light gain tradeoff be given careful consideration. In many cases glazing can be modified to limit heat gain while still permitting entry of a significant amount of light. Such modifications are discussed earlier in this chapter under "Transmission, Glazing.")

√d. Arrange work surfaces so that sidewall daylighting crosses the task perpendicular to the line of vision.

5.3 Maintenance Considerations

Proper maintenance of lighting system components serves to keep the system running at peak efficiency. This not only conserves energy and energy costs, but also helps maintain quality illumination and extends lamp and luminaire life. The following maintenance considerations should be reviewed.

MINIMAL EXPENSE

√a. Lamp efficiency deteriorates over the life of a lamp. Light output should be checked regularly with a calibrated light meter by maintenance personnel. When the light output of a group of lamps has fallen to approximately 70% of the original light output, relamp all fixtures in the group at the same time. This is also a good time to check whether a more efficient or lower wattage lamp is suitable.

b. Lamps should be wiped clean at regular intervals to assure maximum efficiency. Lamps which are exposed to an atmosphere with substantial amounts of dirt, dust, grease or other contaminants should be cleaned more frequently than lamps in a relatively clean atmosphere.

c. Luminaire efficiency can be maintained by properly cleaning the reflecting surfaces and shielding media. Replace lens shielding that has yellowed or become hazy with a clear acrylic lens with good non yellowing properities. For some applications, a clear glass lens can be considered if it is compatible with the luminaire and does not present a safety hazard. (Caution should be used to assure that an existing luminaire will safely support and hold the glass lens.)

d. Clean ceilings, walls and floors frequently to improve reflective qualities. When daylight is used, wash windows frequently to maintain illumination levels on tasks which require some natural illumination.

5.4 Illumination Level Modifications

There usually are at least several levels of illumination required within any building. These levels can be separated into three general categories: specific task lighting, general lighting around tasks, and general lighting for circulation or support areas.

While it is commonly understood that different visual tasks require different levels of illumination, the interiors of many office buildings provide only uniform illumination levels which have little relationship to the amount of illumination required in specific areas.

During a building's original design, the lighting designer frequently cannot define the nature or location of specific tasks or task areas. The designer's problem is often compounded by lack of knowledge about final partition locations, floor and wall finishes and other tenant options, all of which have an impact on the final illumination results.

After a building or space is completely defined or occupied, there usually are opportunities to adjust illumination levels to improve utilization and efficiency. If the wiring and lighting system provides flexibility to allow for relocating luminaires, switching individual lamps or groups of lamps, or otherwise providing means for controlling the lighting in specifically defined areas, the adjustment can be made quickly and inexpensively. In buildings without such flexiblity, it may be necessary to add switching, remove lamps, disconnect or add luminaires, or in extreme cases, remodel the entire lighting system in order to provide proper illuminiation for individual tasks and still accomplish the energy reduction desired.

In general office areas, nonuniform lighting systems can be applied when the average work station size is less than one worker per 50-70 square feet. If work stations are larger, a uniform lighting system is generally more practical. Larger, private offices are areas where nonuniform lighting applications could save energy. Most store lighting requires the use of uniform lighting systems within departments, but illumination levels between departments may vary depending upon the type of merchandise involved. It is also common practice in specialty shops or departments to use relatively low levels of general illumination with some merchandise highlighted by spot or flood lighting equipment. Since space usage usually changes several times over the life of a building, special consideration should be given to providing flexibility in the lighting and control systems.

The examples shown in Figure VI-1 provide some general guides for illumination levels in applications that are encountered frequently. The areas where illumination modifications can and should be made can be determined easily by use of a properly calibrated light meter. Methods to modify illumination levels, reduce energy consumption, and maintain an effective lighting system are as follows:

5.5 Lamp Modification

Lamp modification can take many forms. In some cases it may involve elimination of lamps; using those of lower wattages; changing the type involved (which would imply in most cases a change of luminaire), etc. Consider the following guidelines:

MINIMAL COST

a. Consider replacing present lamps with those of lower wattage which provide the same amount of illumination or (if acceptable in light of tasks involved) a lower level of illumination. (Lens changes or lowering the luminaire often can help). This method is particularly applicable where current lighting levels are higher than recommended or where uniform lighting is the most practical due to occupant density, as discussed above. This also is a simple way to provide flexibility should higher levels of illumination be required at some future time. (Note: Be certain that new lamps are compatible for use with existing ballasts in fluorescent and H.I.D., (High Intensity Discharge) luminaires.)

√b. Remove unnecessary lamps if removal will still enable provision of illumination levels required. When lamps are removed from a fluorescent luminaire, all lamps controlled by a given ballast should be removed to prevent ballast failure or reduced lamp life. Except in the case of instant start lamps or luminaires with circuit-interrupting lamp-holders, also consider disconnecting ballasts which otherwise would continue to consume energy.

c. Replace existing lamps with more efficient versions of the same type of lamp. Numerous different approaches are available. For example, elliptically-shaped reflector lamps have been designed for installation in stack-baffled downlights. A 75W version of this new lamp will provide just as much illumination as a 150W R40 flood, thus cutting energy consumption by 50%. High efficiency fluorescent lamps can provide almost as much light output as less efficient standard fluorescent lamps, and cut energy consumption by 14%.

FIG. VI-1
SUGGESTED ILLUMINATION LEVELS

Office Buildings:	**Footcandles Maintained**
Private Offices	
Reading handwriting in hard pencil or on poor paper, reading fair reproductions	100
Reading handwriting in ink or medium pencil on good quality paper	70
Reading high contrast or well-printed materials	30
Conferring and interviewing	30
General Offices	
Reading handwriting in hard pencil or on poor paper, reading fair reproductions, active filing, mail sorting	100
Reading handwriting in ink or medium pencil on good quality paper, intermittent filing	70
Bank Lobby	
Writing Areas	70
General Areas	50
Dental Offices	
General Operatory	70
Waiting Rooms	30
Doctor's Offices	
General Examination and Treatment	50
Waiting Rooms	30
Conference Rooms	
Conferring	30
Note-taking during projection (variable)	30
Rest Rooms and Wash Rooms	30
Corridors, Stairways, Elevators	20
Storage Rooms	
Active — Medium Materials	20
Active — Rough, Bulky Materials	10
Inactive Storage	5
Stores:	
Merchandise requiring close inspection because of detail, fineness, or high value	100*
General Merchandise Areas	50*
Alteration rooms, fitting rooms, dressing areas	50
Circulation areas, stockrooms	30

Illumination levels above are from Illuminating Engineering Society Handbook, 5th Edition. Guidance for special situation and more difficult and critical tasks may be found in the Handbook. It will be noted that most of the higher levels therein are intended to be provided by localized lighting involving relatively small amounts of energy. Consideration should also be given to the lighting needs of older workers with regard to illumination levels and minimum glare.

***Footcandle values on plane used to display merchandise. Horizontal plane for merchandise displayed horizontally. Vertical plane for merchandise displayed vertically.**

Footcandle values above are excerpted from the IES handbook, which also provides additional information on lighting for other tasks. These illumination levels are also specified in the Model Code For Energy Conservation In New Building Construction.

d. **Replace existing mercury vapor lamps with more efficient metal halide or high pressure sodium lamps designed specifically for the purpose. The retrofit lamps consume less energy and provide far more light. As such, fewer lamps may be needed. Note, however, that there are different types of mercury vapor luminaires. The replacement lamps are designed for one type of mercury vapor ballast only.**

e. **Consider use of light-reducing fluorescent lamps. When one of these new fluorescents is installed in a two-lamp fixture, the light output and energy consumption of both lamps is equivalent to 33% or 50% of original. These lamps should be used only when reduced light output is consistent with needs in the space.**

f. Consider replacing existing lamps with more efficient lamps of a different type. A range of lamp efficiencies including ballast losses is shown in Table VI-1.

Use of different lamps will in most cases require replacement of existing luminaires.

5.6 Luminaire Modifications

Luminaire efficiency is indicated in terms of "coefficient of utilization." While efficiency is an important consideration in luminaire selection, one also must consider visual comfort. The following guidelines are provided for the three general types of application:

TABLE VI-1. APPROXIMATE RANGE OF LAMP/BALLAST CHARACTERISTICS

		Average Lumens Per Watt Including Ballast Losses				
Type of Lamp	**Wattages**	**Initial**	**Mean**	**% Lumen Maintenance**	**Average Rated Life (Hours)**	**Warm-up/ Restrike (Minutes)**
Low Pressure Sodium	18-180	62-150	60-143	100	10-18,000	7.00/0-1
High Pressure Sodium	70-1000	79-130	71-118	90-91	20-24,000	3-4/.5-1
Metal Halide	175-1500	69-105	54-84	77-80	10-15,000	2-5/10-20
Mercury Vapor	50-1000	30-60	23-46	75-89	16-24,000-	5-7/3-6
Fluorescent	40-215	63-100	42-88	66-88	12-20,000-	Immediate
Incandescent	60-1500	15-24	13-23	90-95	750-2500	Immediate

Note: Approximate range of lamp/ballast combination characteristics are based on data applicable to most commonly used lamps within each lamp category. Data are provided for general comparative purposes *only*. Actual performance of a lamp with regard to any of the factors indicated will vary due to the uniqueness of a specific installation. Efficiency of an installation depends on far more than lamp or lamp/ballast efficiency.

Source: The National Lighting Bureau, Washington, D.C.

- For tasks where veiling reflections are a critical factor and visual comfort is important, the luminaire can have a coefficient of utilization of .55 or higher. It also should have high visual comfort.
- For spaces where veiling reflections are not a critical factor, but where visual comfort is still a factor, the luminaire can have a coefficient of utilization of .63 or higher, and medium to high visual comfort.
- For spaces that do not involve critical visual tasks, and where visual comfort is not a factor, the luminaire can have a coefficent of utilization of .70 or higher and low visual comfort.

More specific information regarding coefficients of utilization and visual comfort can be obtained from the Illuminating Engineering Society Lighting Handbook and from manufacturer's data for specific luminaires.

Some of the modifications to luminaires which are possible include the following:

SIGNIFICANT EXPENSE

a. Relocate luminaires to provide light on task areas at an angle outside the zone which causes veiling reflections if relocation of work station is impractical.
b. Replace outdated or damaged luminaires with modern luminaires which can be easily cleaned and which use lamps with higher efficiences and good lumen maintenance characteristics.
c. Consider installing fluorescent luminaires with two-level ballasts or adding dimming controls in multiple-purpose spaces which require more than one level of illumination.
d. Consider lowering luminaires so they will provide recommended illumination levels on the task area at reduced wattage.
e. Where appropriate, consider installation of lenses which provide special light distribution patterns to increase lighting effectiveness. As examples, linear batwing, radial batwing, parabolic louvers or polarizing lenses may provide better visibility with the same or even reduced wattage. It is suggested that competent technical advice be obtained to evaluate where such lenses can be used most effectively.

5.7 Control Modification

In many cases modification of existing lighting controls, and addition of new ones, can have a considerable effect on energy consumption. Consider the following guidelines:

MINIMAL EXPENSE

a. When existing circuitry makes it impossible to utilize less than 25% of the light in a given large space whenever light is needed, and when persons work during normally unoccupied periods, consider development of a desk lamp issuance program which enables persons working during unoccupied periods to use a simple desk lamp or two instead of a large bank of luminaires.
b. When natural light is available in a building, consider the use of photocell switching to turn off banks of lighting in areas where the natural light is sufficient for the task.
c. Use photocell and/or time clock controls for outdoor lighting whenever feasible. Parking areas, building exteriors, identification signs, etc., usually require lighting for only a part of the period of darkness. Such lighting should be turned off automatically during late evening and early morning hours except for security and safety lighting.
d. Use time controls for those areas of a building which are used infrequently and only for brief periods. These controls turn off lights automatically after being activated for a set period of time.
e. Use alternate switching or dimmer controls when spaces are used for multiple purposes and require

different amounts of illumination for the various activities. It is possible to provide multiple levels by providing switching for alternate fixtures, alternate sets of lamps in fluorescent fixtures, etc. Dimmer controls can be effective when it is impractical to use selective switching to obtain multiple lighting levels. This is especially true (and relatively low in cost) when incandescent lighting is involved.

SIGNIFICANT EXPENSE

f. Provide selective switching. Initial cost economies and lack of knowledge about final space subdivision often lead to the use of central panel-boards as the only means of controlling large blocks of lighting. This design approach precludes the potential for turning on only the amount of lighting that is actually needed after the space has been subdivided.

Investigate ways to provide local control of lighting. Localized switches can be provided near doorways. Remotely controlled switches can be located near panelboards to control groups of lights. Low voltage control circuits can be used to provide local control of switches located in remote locations (these controls usually are relatively inexpensive). When properly used, localized switching usually will save enough energy to provide a pay-back on the investment within a short period of time.

g. Lighting use in remote areas can be monitored by providing neon indicator lights at central stations. Personnel will be alerted to investigate and turn off lights not being used.

5.8 Heat of Light Recovery Systems

SIGNIFICANT EXPENSE

a. Heat of light recovery systems — because of the expense they entail—usually are feasible only if modernization programs are involved. While many different types are available, most provide the same basic functions. In essence, the heat produced by lighting is extracted by mechanical equipment through a ceiling cavity to the mechanical equipment room. The heat collected can be recycled to reduce heating energy needs in cold weather or discarded to reduce the cooling energy needs during warmer weather. Removal of heat in this manner usually enables luminaires and lamps to operate more efficiently and also may reduce fan horsepower requirements of the air circulation system.

6. DOMESTIC HOT AND COLD WATER

Domestic hot water often consumes from 2% to 4% of the total energy used in large office buildings. In retail stores and smaller buildings, the amount usually is smaller. Cold water, provided in drinking fountains, also is a factor in total building energy consumption. The following guidelines should be considered in an effort to conserve energy:

MINIMAL EXPENSE

√a. Inspect water supply system and repair all leaks, including those at the faucets.

√b. Inspect and test hot water controls to determine if they are working properly. If not, either regulate, repair or replace.

c. Inspect insulation on storage tanks and piping. Repair or replace as needed.

d. Increase the amount of insulation installed on hot water pipes and storage tanks or replace existing insulation with a type having better thermal properties ("R" value).

e. Consider replacing existing hot water faucets with spray type faucets with flow restrictors where practical.

f. Consider installing spring activated hot water taps.

g. If water pressure exceeds 40 to 50 pounds, consider having a plumber install a pressure reducing valve on the main service to restrict the amount of hot water that flows from the tap.

h. Reduce generating and storage temperature levels to the minimum required for washing hands, usually about 105°F. Boost hot water temperature locally for kitchens and other areas where it is needed, rather than by providing higher than necessary temperatures for the entire building.

i. If cooking facilities are used only on occasion, as for certain conferences or meetings, deactivate the hot water heating system, including the gas pilot if installed, when the facilities are not being used.

j. If you have an electric domestic water heater, consider limiting the duty cycle to avoid adding water heating load to the building during periods of peak electrical demand.

√k. If hot water is distributed through forced circulation, turn off the pump when the building is unoccupied.

√l. Disconnect all refrigerated water fountains if acceptable to building occupants.

√m. Discontinue sterilization of drinking water where possible and practical.

n. Consider relocating the water heater as close to the point of use as possible. The longer the run, the more hot water that sits in it — cooling down — between periods when hot water is drawn.

o. Consider replacing free running drinking fountains with spigot types which utilize a paper cup. Up to half the water drawn by free-running fountains is wasted.

7. ELEVATORS AND ESCALATORS

Despite the fact that escalators draw relatively little current under no-load operation, it generally is recognized that their continuous action does tend to waste energy. Although intermittent, as-needed operation can be obtained through use of a treadle-type switch, relatively few such installations have been made due to safety concerns. When an escalator is shut down, however, it still provides a means of transportation: stationary stairs. By contrast, an elevator cannot serve any useful purpose when it is nonoperational. When elevators are running, however, they tend to be more efficient than escalators, although they do cause indirect energy consumption due to stack effects created by the shaft and infiltration around cabs.

Following are a few of the options which should be considered in an effort to provide the elevator/escalator service required while conserving energy in the process. It should be noted that some of these options are mutually exclusive. In other words, if you pursue one given option, it would be impractical or impossible to pursue another. Determination of which options best suit your needs can be made only after careful review of traffic patterns, elevator controls, etc. If possible, contact the manufacturer, his representatives or distributors, to obtain assistance in performing such a review.

MINIMAL EXPENSE

√a. **Encourage building occupants (and perhaps visitors) to use the stairway when only a few stories are involved and when security permits.**

b. **Perform a traffic review to determine if a building is properly elevatored, or over or under-elevatored in light of use during different periods of the day. If properly elevatored or overelevatored, take one or more elevators out of operation at least during periods of light traffic.**

c. **If your building has automatic load-shedding or demand-limiting equipment, connect elevators to the system to enable automatic shut-down of one or more to limit peak demand.**

d. **If elevators are taken out of service, waiting period (floor dwell time) automatically will be increased. If none are taken out of service, however, floor dwell time can be lengthened thus increasing the passenger load factor.**

e. **If elevators have demand type controls, adjust controls so that the fewest number of elevators travel the shortest distance that demand on the system allows.**

f. **Do not permit elevators to time out and shut down too rapidly. They should idle long enough so that power consumption is equal to or just less than power consumed in motor generator starting.**

g. **If escalators are involved, consider these alternatives:**

- **operate them only during peak periods, or**
- **shut down all "down" escalators at all times, or**
- **shut down all "down" escalators during periods of light traffic, or**
- **shut down "up" escalators on every other floor during light traffic.**

SIGNIFICANT EXPENSE

h. **Consider installing capacitors at points of utilization to increase power factor and so reduce kWh losses (and resulting power costs) in the internal distribution system.**

i. **Consider utilizing solid state motor drives instead of motor generator sets. Solid state motor drives typically provide energy savings of from 25-30% as compared to motor generator sets.**

j. **Consider installation of demand-type elevator controls on elevators having through trip or collective type of controls so elevators may be adjusted to ensure that the fewest number of cabs travel the shortest distance which demand on the system allows.**

8. ELECTRIC POWER

Numerous elements of building systems which utilize electricity have been discussed throughout this section. Additional guidelines for reduction of electric energy consumption and losses are as follows:

8.1 General

a. Through letters, memoranda, signage, personal contact and other means, encourage all building personnel to turn off all electric equipment not in use, including portable fans, typewriters, calculators, coffee pots, etc.

√b. Turn off window displays and revolving signs at least at the end of closing hours, possibly during low traffic periods, and perhaps at all times.

√c. Disconnect all unnecessary apparatus and devices, for example, ventilation fans in elevators where smoking is not permitted.

√d. Turn off equipment and devices which will be unused for a period of time, for example, vending machines (in which spoilage would not be a problem) and drinking fountains which can be turned off for the weekend. (You may wish to consider time controls to do the job for you. It would be feasible, then, to also turn off such devices during the evening hours.)

8.2 Utility Cost Management

As you probably are aware, utilities have several different rate structures and, in many cases, more than one may be applicable to your building. As you may not be aware, however, the utility does not automatically bill you at the most favorable rate. In other words, if a new rate structure has been instituted since your building was built, and if the new rate can be used in your building, it will be up to you to know whether or not the new rate is more favorable. The utility will tell you, but you are the one who must ask. As a result, it is suggested that you gather information which relates to purchased utilities, especially the electric utility. In many cases it will be discovered that a more favorable rate is available or can be made available, errors in billing have been made, meters are not working properly, or that other situations and circumstances exist which can be changed to attain positive impact.

You also should be aware of what the utility has planned for the future to aid in your own forecasting and planning. This information can be obtained from the local utility and from your state public service commission.

8.2.1 Review Rate Structures

Many electric utilities have ten or more different services, each often subject to one or more riders. Contact an appropriate utility representative to find out what different rates, services, schedules and riders are available. Most have customer service representatives who can explain utility operatins and go over yours to suggest ways of economizing. Once you are familiar with utility materials, determine for every separate service location:

- rate schedule and riders used;
- maximum demand and period of occurrence;
- power factor;

- monthly and annual energy consumption;
- average cost per kWh;
- service voltage level and secondary use level, and
- transformer and equipment ownership.

Talk with other electric customers in a position similar to your own. Determine what rate schedules they're using, what their use characteristics are, and how much they're paying. Make a complete and careful review of at least one current bill for each service and ask yourself: "Am I getting the appropriate rate?" "Is the bill computed properly?" "Why am I on this rate?" "How can I qualify for a better rate?" Seek a satisfactory answer to *each* question. Contact a utility representative for help and work with him to develop a program and rate which best meets your needs and conditions. Have him come in to review each service. Ask him if other rates apply or could be made to apply. Determine advantages and disadvantages of each. Check figures.

Your utility representative will tell you about the alternatives if you ask, but it's up to you to make a decision. If you do decide to change rates, determine what the impact will be—if any—on building systems.

8.2.2 Utility Bills

All utility bills for should be reviewed. In fact, there are companies which will do this for you, taking 50% of the refunds you obtain as their fee (see paragraph 8.2.3).

In most cases, a bill will include charges for:

- *Energy:* Most electric utilities use a sliding block approach for energy charge, that is, so much per kWh for the first 1000 kWh, so much per kWh for the second thousand, and so on. In most cases, the more kWh you consume, the less per kWh you pay.
- *Fuel Adjustment:* Many electric utilities have imposed an additional energy cost called a fuel adjustment which reflects the increased cost of fuel. It can be a substantial charge. (Gas utilities have something similar called a purchased gas adjustment charge (PGA) which reflects adjustment to gas bills based on fluctuations in the wholesale cost of gas.)
- *Customer Related:* Some utilities add what's called customer-related costs. These comprise a special charge which reflects part of the distribution investment, part of the operating and maintenance costs, costs for accounting and collection, and so on. If it isn't billed separately, it may be included with the energy cost.
- *Demand:* The demand charge is designed to make the customer pay his fair share of the utility's fixed investment in the production, transmission and distribution equipment required to meet his maximum requirements. The charge is based on the rate at which electricity is consumed. The more used at any given time, the larger the utility's investment in generation, transmission and distribution systems has to be. For example, consider two users: A and B, both consuming an equal number of kWh each day. User A consumes electric energy 24 hours a day and user B consumes it 8 hours a day. User B requires the ability to have generating and distribution capacity equal to the ratio of 6/2 times the capacity required to supply user A. This is 3 times the capital investment that was required to serve user A, so user B is billed for this extra investment.

  The consumer's actual demand is computed as the average amount of energy consumed in a predetermined demand measurement interval, usually 15 minutes (other intervals also are used by the utilities, particularly 30 minutes and 60 minutes). Regardless of the interval, the highest demand recorded during a month becomes the actual demand for the month.

  Many utilities also employ a special clause which states that no matter what your actual demand may be in any given month, the demand for which you are *billed* may be no less than a certain percentage of a demand recorded typically — during the summer months. This already has been discussed in Chapter IV.
- *Low Power Factor Penalty:* Another charge sometimes applied, is a penalty for low power factor, a subject discussed in paragraph 8.8.

8.2.3 Utility Consultants

You may find it desirable to call in a utility consultant to just check your figures or, at the other extreme, to perform an all-out research effort. There are three basic kinds of consultants: consulting engineers, electrical contractors, and contingency fee consultants.

A consulting engineer typically undertakes the work required for a fee so you will have a reasonably good idea of what to expect in terms of your cost. The electrical contractor usually works on the same basis or may follow the procedure used by a contingency fee consultant who is paid on the basis of how much money he saves you. A typical contract calls for a flat service fee plus additional fees for savings. In addition, the company will research your utility needs and will look for any refunds due you.

Obtain background data on at least three firms. Review the data and contact the firm's clients to see how satisfied they've been. Then meet with representatives of each of the three firms and form an opinion.

If you're going to use a consultant on a contingency fee basis, be aware that any standard contract can be modified.

While it may be true that a contingency-fee contract will result in a more thorough search being made to find you refunds and savings, realize, first, that this is not *always* true and, second, that you *may* wind up paying more on a contingency basis.

8.3 Maintenance

A proper program of electrical system maintenance can help prevent excessive energy losses, reduced equipment life, and hazardous conditions associated with poorly maintained equipment.

As an initial step, a load survey of the building's electrical distribution system should be made by a qualified professional electrical contractor. Although probably adequate when first designed and installed, the system may not now be able to carry proper current due to changes in layout and uses. Additions or shifts in motors may have affected working voltage of the system, thus affecting motor operation, lighting efficiencies and conductor loading. The load survey

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should indicate problem areas. As examples, low voltage conditions on motors cause high amperage draw which increases line losses. Overvoltage causes some motors to become less efficient. Undersize wire increases line loss. Loose connections and bad contacts cause increased amperage draw and power loss as well as heating and arcing which is both inefficient and dangerous. Unbalanced voltages in three-phase motors can create inefficient motor operation. Power leaks to ground also can cause substantial loss of energy, arcing and, ultimately, loss of life.

Assuming that repairs and maintenance are performed as needed, regular checks of voltage at the terminals of power and lighting circuits should be made. Constant rated voltage is necessary to obtain maximum efficiency and usable life from installed equipment.

Systematic records should be kept of all surveys, regular checks, maintenance and investigation performed, etc. In this manner you will be able to determine when correction is required, whether equipment is failing, etc.

8.4 Equipment and Control Rooms

Water, dust, heat, cold, humidity, dryness, corrosive atmospheres, vibration and other conditions all affect the performance and usable life of electrical apparatus. For this reason, it is essential to regulate to as great a degree as possible the environment of equipment and control rooms where the majority of electric apparatus are located. It is suggested that such rooms be kept relatively dry and that appropriate ventilation be installed for enclosed rooms to prevent heat build-up. High humidity can increase dirt build-up on electrical parts and cause inefficiencies and, in some cases, total breakdowns.

8.5 Power Transformer Management

Proper management of transformer operation and related factors can result in significant energy savings. The following guidelines should be considered:

a. Shade exterior transformer banks from solar radiation to prevent heat build-up and resultant losses.
b. Ventilate transformer banks to keep them as cool as possible.
c. De-energize transformers whenever possible, including:
    i. Unloaded transformers
    ii. Transformers supplying unoccupied or unused spaces
    iii. Refrigeration chiller transformer during the heating season
    iv. Heating equipment transformers during the cooling season
    v. Heating and cooling transformers during periods of time which normally require no heating or cooling, as during spring and fall.
d. When replacing transformers or adding new ones to the system, select those designed for a lower temperature rise but furnished with high temperature rise insulating materials.

8.6 Outdoor Switchgear

Because heat can increase energy losses of switchgear, consider the following guidelines for that switchgear located out-of-doors:

✓a. Provide shading
✓b. Remove or prune (in the case of shrubbery) any obstructions which tend to diminish natural ventilation.

8.7 Demand Management and Control

The effectiveness with which energy is used is rated is expressed in terms of load factor: the ratio of energy use (kWh) to highest demand (kW) × time, usually measured as 720 hours—the number of hours in 30 days. For example, if you consume 700,000 kWh in a 30-day period and during that time establish a peak demand of 1500 kW, you'd have a load factor of 64.8%.

In essence, the lower the demand, the higher the load factor. The higher the load factor is, the lower the relative cost for electric service.

The techniques used most often to improve load factor are demand management and demand control. The two are not synonymous terms. Demand control refers to the elctromechanical procedure of load shedding. Demand management encompasses demand control as well as other activities which can help reduce demand charges even more.

8.7.1 Analyze Operations

To determine potential for improving load factor, analyze demand records to determine when demand peaks typically occur during operating hours. Observe operations to determine what in particular is responsible for peaks. Once you find that out, determine what you can do to sequence processes or events to hold peaks down. If two pieces of equipment are started simultaneously, for example, could start-up times be sequenced so surges do not occur at the same time? Could some operations be scheduled so that one begins after the other ends?

The demand savings to be obtained this way usually require no capital expense and they can be significant.

8.7.2 Develop Load Data

The specific research data you need to develop a demand control system specification may or may not be on hand. Essentially what is needed is information on the rating of each electrical load. If comprehensive as-built drawings are available, the task should be relatively simple. If not, consider making a power survey using a recording wattmeter or other instruments to develop accurate data on how much power is being used by equipment at a particular time. Other information you should collect relates to any expansion or alternation planning which could somehow have a bearing on future demand requirements.

8.7.3 Identify Primary and Secondary Load

Each load should be identified as either primary or secondary.

A primary load is one which cannot be interrupted. A secondary load is one which can be interrupted, rescheduled or deferred and cause no problems in terms of comfort, process or productivity.

Typical secondary loads include: lighting, electric heating units, electric cooling units, chillers, air handling units, exhaust fans, water heaters, pumps, electric boilers, furnaces, ovens, incinerators, air compressors, loading dock de-icers, snow melting systems, and escalators, among others.

8.7.4 Analyze Secondary Loads

Once secondary loads are identified, Determine their wattage ratings and establish an order or priority. The more essential secondary loads should be listed first so they can operate last-out-first-in while lower priority loads operate first-out-last-in. Before making any decisions, analyze the impact of shedding for each load. To do this, first determine the negative impact which shedding the load will have on process, comfort, productivity or environment. Second, determine the negative impact on the equipment itself. Frequent operation of controls usually will shorten expectant life and increase maintenance costs. So the factors have to be related to savings in electrical costs.

Once controllable loads and priorities are identified, determine how much demand reduction can be allowed and the economics of various types of demand control systems.

8.7.5 Demand Control Systems

To select a specific demand control system, it should be noted that each system comprises three essential elements:

a. **Input**

Input to most demand control systems is in the form of pulses from the utility's kilowatt-hour meter incorporating a demand meter attachment. Each time a certain number of kilowatt hours accumulates, a pulse is generated. At the end of each interval the meter gives off an end-of-interval of EOI pulse. The pulse tells the control device that the interval is over and that new interval has begun.

b. **Logic**

Logic refers to the operating method by which an automated demand control device performs its function of measuring the energy being consumed in the facility and limiting demand by shedding certain secondary loads.

Demand control equipment available today ranges from relatively inexpensive units to highly sophisticated, large-scale computer systems. Some systems are not automated at all and work by shutting down equipment or sounding an alarm whenever the desired maximum demand is exceeded. Although this type of unit is applicable for some installations, it does not lend itself to highly effective control. Desired maximum demand frequently is overshot because action usually can't be taken until it is too late. In most instances an automated demand control is preferable.

The five logic systems generally used are described as follows:

i. **Ideal Rate Demand Control Logic:**
Accumulates and compares actual rate of energy used in any demand interval to a predetermined, ideal rate of use. As actual rate of consumption approaches ideal rate, secondary loads are shed. As consumption rate declines, secondary loads are restored.

ii. **Converging Rate Demand Control Logic:**
Similar to ideal rate, except ideal use curve and shed and restore lines converge at the end of each interval rather than run parallel to each other. This enables finer control over relatively small loads late in the demand interval when accumulated registered demand may be very close to the maximum desired demand setpoint.

iii. **Instantaneous Demand Control Logic:**
Compares actual rate of consumption at any time in the demand interval to maximum desired consumption at that time. Assume that maximum desired consumption is 1000 kW for a demand interval. With straight-line accumulation or constant usage, the accumulated demand should be no more than 250 kW at one-fourth of the interval and 500 kW at one-half of the interval. Loads are shed and restored according to this criterion.

iv. **Continuous Integral Demand:**
Similar to instantaneous demand because usage is continually monitored and compared to the desired maximum rate. When actual rate approaches maximum desired rate, a secondary load is shed, but actual shedding function is carried out by a satellite cycle timer which deactivates the secondary load for a fixed period of time. This results in demand interval overlap. For example, if a secondary load which stays deactivated for six minutes is shed at 14 minutes into a 15 minute demand interval, it is going to stay shed for the first five minutes of the following interval. Continuous integral demand controllers compare the present usage to usage in previous intervals without restoring all loads at end of each interval. This reduces excessive short cycling of equipment and operations.

v. **Predictive Demand Control Logic**
Measures total accumulated energy consumption from beginning of demand interval. A predicted or projected end-of-interval demand is developed based on the rate of accumulated consumption measured at each point and the rate multiplied by the time remaining in the demand interval. If the predicted demand exceeds minimum desired demand, a secondary load is shed. If a subsequent measurement indicates a large enough margin, secondary loads are restored. Predictive method systems generally can accommodate a wide variety of load profiles and, in most cases, are more expensive than other types. They also

must be compatible with utility demand metering equipment for synchronous operation.

c. Output

The output function of automated demand control systems acts on logic decisions and provides the actual control. This is accomplished by activating relays, contractors, or motor starters which shed or restore loads on the line. The sequence in which secondary loads are shed can be altered. In some cases it can be specified that a given load is the last shed and first restored, or first shed and last restored, and so on.

8.8 Power Factor Improvement

The power which must be supplied to any induction load such as induction motor, transformer, fluourescent lamp, etc., is made up of real and reactive power.

Real power, or the working power, is measured in kilowatts (kW). The reactive, or magnetizing current, is required to produce the flux necessary for the operation of any induction equipment. Without magnetizing current, energy could not flow through the core of a transformer or across the gap of an induction motor. The unit used to measure reactive power is the kilovar or kVAR. The *vector* sum — *not* the arithemetical sum—of the real power and the reactive power is the *apparent power*, measured in kilovolt-amperes or kVA.

Power factor is a ratio of real power (kW) to apparent power (kVA) or,

$$\text{Power Factor} = \frac{\text{Real Power (kW)}}{\text{Apparent Power (kVA)}}$$

Electric utilities must provide both real and reactive power for their customers. Reactive power does not register on a kilowatthour meter, but producing it still requires the utility to put additional investment into capacitors and generating, transmission and distribution facilities.

Many utilities make up for the expense of producing reactive power by including power factor provisions in their rates. As it so happens, many utilities are defining low power as anything less than .9. Thus if a building consumes 10 million kWh per year at 3.5 cents per kWh and has a power factor of .87, its penalty would be:

$$\frac{\text{kWh/Yr}}{\text{Power Factor}} - \frac{\text{kWh/Yr}}{.9} \times \text{kWh rate}$$

$$\frac{10{,}000{,}000}{.87} - \frac{10{,}000{,}000}{.9} \times \$.035$$

$$= \$13{,}409.03$$

Practically speaking, a power factor improvement or at least a review of power factor economics is indicated for any building that purchases at primary level or on a large commercial power rate, or which maintains one or more of its own electric substations. More specifically, *some power factor improvement will prove worthwhile if your electric use meets one or more of the following conditions:*

- power demand is recorded on bill (in kVA);
- electric rate has a kVAR or power factor penalty clause;
- there are problems with voltage regulation or chronic low voltage, or
- load growth limits spare capacity and you need more capacity.

Causes for low power factor typically are lightly loaded motors which draw excessive amount of reactive power and increase energy losses in the overall distribution system. Power factor correction can be made through installation of capacitors at utilization equipment locations. Costs of equipment and installation usually can be paid back quickly, if (and only if) the utility charges for reactive power supplied. It is advisable to review the need for and amount of power factor correction on specific types of loads with either the utility, equipment manufacturer, or your consultant.

9. COMPUTER FACILITIES

Recent research shows that buildings with significant computer installations frequently consume as much as 1.5 and more times the amount of energy consumed by buildings without such installations. While the computer equipment itself obviously consumes energy, researchers feel that the primary reason for the high energy consumption rate is the extent to which the computer support facilities and equipment are in use. Typically, computer operations extend into periods when a building would otherwise be unoccupied — evening, late evening, early morning, weekends, etc. In some cases computer operations continue around-the-clock. As a result, the building systems required to support computer equipment and personnel — HVAC, lighting, food service, elevator, and other systems—also must be operational and so consume energy. Given the extensive amount of work performed by computers and those who man them, as well as their high rate of productivity, suggestions that their use be reduced to conserve energy would be out of the question. Nonetheless, there are steps which can be taken to at least ensure that no more energy than is necessary is used to support computer operaations.

MINIMAL EXPENSE

√a. Consult manufacturers to determine permissible temperature and humidity ranges. Adjust controls of computer-support HVAC equipment to provide those conditions which are acceptable and which will result in the minimum expenditure of heating/cooling/humidification/dehumidification energy.

√b. Reduce lighting levels to those minimums suggested by the computer equipment manufacturer.

√c. Develop a checklist for use by computer personnel. Such a checklist should include directions on operation of the building's lighting, HVAC, food service, elevator and other systems during periods of general building nonoccupancy. In that it is the use of other-than-computer equipment which, it is felt, contributes most to the higher energy consumption of buildings with computer installations, this step is of particular importance.

SIGNIFICANT EXPENSE

d. Modify the HVAC system to permit independent conditioning of air in those areas, such as computer rooms, where special conditions are required. To provide computer-required conditions to areas where such conditions are not required can result in a significant waste of energy.

e. Modify the lighting system to provide proper illumination and selective control to enable energy savings particularly during extended periods of operation when the building otherwise would be unoccupied.

f. Consider installation of systems to recover heat produced by computer equipment and computer-area lighting for use elsewhere.

10. INTERIOR SPACE UTILIZATION

The way in which interior building space is utilized by occupants can have a pronounced effect on energy utilization as well as on business productivity. Some of the potentially beneficial modifications which should be considered include:

10.1 Work Methods Improvements

MINIMAL EXPENSE

√a. Consider combining operations and work elements, changing sequence of operations, simplifying necessary operations, eliminating unnecessary work, and establishing preferred work methods. In this way, for example, trips between floors via the elevator can be reduced if several routine tasks can be undertaken while on the floor involved, instead of making two or three trips to perform each task separately.

10.2 Equipment and Materials Relocation

MINIMAL EXPENSE

√a. Consider locating all computer and computer-type equipment which requires close temperature and humidity control in a common space to be served by a common system.

√b. Where practical, place all heat-producing equipment such as duplicating machines in one area to enable easier control for heating and cooling purposes.

√c. Locate wall hangings, displays and furniture away from supply and return air grilles and registers to prevent obstruction of air flow.

SIGNIFICANT EXPENSE

d. Consider removing partitions to create an open space effect which will permit much freer movement of air and a reduction in lighting requirements.

10.3 Other

MINIMAL EXPENSE

√a. Close off unused areas and rooms. Where possible, be certain that blinds or other shading devices are drawn, registers closed, etc.

√b. If possible, have persons working after hours work in proximity to one another to lessen lighting and HVAC (heating, ventilating and air-conditioning) requirements.

√c. When repainting, consider use of light wall surfaces to reflect both heat and light.

√d. If possible, place in proximity to one another those persons whose tasks require similar lighting levels.

11. ADVANCED TECHNOLOGIES

For our purposes, advanced technologies are those which include waste heat reclamation systems, energy management and control systems and solar energy systems. The applicability of any one of these technologies, or specific versions of them, depends on numerous different factors. Any of them, in general, requires substantial capital expense. In some cases, however, paybacks can be surprisingly rapid. For example, an energy management and control system can cost as much as $200,000 and more. Nonetheless, numerous case histories show paybacks of three years and less; in some cases, less than two years.

11.1 Waste Heat Recovery Systems

Waste heat recovery results in utilization of heat energy that otherwise would be rejected to waste. As such, heat recovery conserves energy, reduces operating costs and reduces peak loads.

The following discussion is intended to provide some basic information on the types of heat recovery systems available and some of their general applications. See also discussion above under 3.5 (a) (Boiler Stack Economizer), 3.5 (b) (Preheat Oil To Increase Efficiency), 3.5 (c) (Preheat Combustion Air to Increase Boiler Efficiency), and 5.8 (Heat of Light Recovery Systems).

a. Rotary Heat Exchanger

The rotary heat exchanger uses a heat transfer medium in the form of a cylindrical drum or wheel. When rotated slowly between the supply air stream and exhausted air stream it absorbs heat from the warmer air stream and rejects heat to the cooler air stream. In addition to sensible heat transfer, the wheel can be hygroscopically treated with a desiccant which transfers water vapor from the humid air stream to the drier air stream. Non-hygroscopic wheels transfer water vapor when the temperature of one air stream is below the dew point temperature of the other and there is direct condensation of water vapor. During operation at temperatures below 32°F, freezing usually is prevented by preheating the supply air.

Rotary heat exchangers are normally economical for all applications of 4000 cfm or more of ventilation air. Operating at approximately 8 to 10 rpm with a face velocity of 550 fpm, the non-hygroscopic rotary exchangers recover 70 to 80% sensible heat and 40 to 60% latent. Hygroscopic or enthalphy exchangers recover 70 to 80% total heat.

The location of the supply and exhuast ductwork in close proximity of each other can be an obstacle in many applications especially when exhaust streams are contaminated. In these cases, purge sections must be added to the wheel and special filtration may be necessary in the supply air.

b. Air-to-Air Heat Exchangers

Air-to-air exchangers transfer heat directly from one air-stream to another through direct contact on either side of a metal heat transfer surface. This surface may be either convoluted plate (more common for low temperature use in HVAC system) or tube (more common for boiler flue gas heat transfer). Air-to-air heat exchangers may be purchased as packaged units or can be custom made. They transfer sensible heat only and are not designed for cooling applications. Size is limited only by the physical dimensions of the space available.

The efficiency of each installation and cost should be calculated based on the particular circumstances that apply. Although efficiencies of air-to-air heat exchangers generally are below 50%, it must be recognized that they are relatively inexpensive, have low resistance to air flow, require no motive power input, and are trouble-free and durable.

c. Run-Around System

A limitation associated with passive heat recovery devices is that the supply and exhaust duct work must be close together. In some applications this may be physically impossible. In addition, cross contamination caused by leakage from exhaust to supply streams may be unacceptable when the exhaust contains noxious or poisonous fumes, or if there is a need for cleanliness. Both of these disadvantages can be overcome by using a run-around system which consists of finned-tube water coils located in the exhaust and supply air streams, and a pump circulating water or a water/antifreeze solution between the coils. In this form the system is for sensible heat recovery only. It is seasonably reversible, preheating in the winter and precooling in the summer. As with other heat recovery devices, the coils are subject to corrosion, condensation and the possibility of freeze-up.

Coils and pump are normally selected to achieve sensible recovery efficiencies of 40% to 60%. Greater efficiencies can be achieved by adding more coils in the heat exchangers to increase their capacity. When finned tubing is added, however, the pressure drop across the coil increases and more fan power is required for the supply and exhaust system. Additional tubing also increases the pumping horsepower required, so gains in efficiency will be partially offset by increased power requirements.

If latent recovery is necessary, the system can be modified by replacing the water coils with a cooling tower surface. Therefore, an additional solution pump is needed to complete the system. This provides total heat or enthalpy transfer as the solution absorbs heat and water vapor from the air streams, and also acts as an air washer or scrubber.

d. Heat Pipe

A heat pipe is a passive heat exchanger which involves a closed fluid cycle within a sealed tube. Cool air passing over one end of the tube is heated when it condenses the fluid enclosed in the tube. The warmer air stream passing over the other end of the tube is cooled when it evaporates the fluid contained in the tube. The action is reversible and operates whenever there is a temperature difference between either end of the tube. Any range of supply air cfm can be handled by the addition of more tubes to the heat exchanger rack. Because they contain no moving parts, there is minimal leakage between air streams. Mechanical energy is not used except in the form of increased fan horsepower to overcome static pressure losses. Note that the supply and exhaust ductwork must be brought into close proximity to each other.

e. Shell and Tube Heat Exchangers

Shell and tube heat exchangers can be used to exchange heat in liquid-to-liquid, steam-to-liquid, and gas-to-liquid configurations. All three configurations are commercially available in a wide range of sizes and outputs and with reliable heat exchange data. Particularly favorable applications are to capture energy from hot condensate, hot refrigerant gas, condenser water, and hot drain lines from kitchens and laundries. Heat exchangers should be insulated to prevent unnecessary heat loss and should be constructed of materials to suit the application.

f. Double Bundle Condenser System

A double-bundle condenser is constructed with two entirely separate water circuits enclosed in the same shell. Hot refrigerant gas from the compressor is discharged into the condenser shell where its heat is absorbed by either one of the water circuits or by both simultaneously depending on the requirements of the system at a given time. One of the circuits is called the building water circuit and the other the cooling tower circuit. The condenser is split into two independent hydronic circuits to prevent contamination of the building water and its associated pipes, coils, pumps and valves with cooling tower water, which may contain dirt and corrosive chemicals. When a double-bundle condenser is added to a standard refrigeration machine the heat rejected by the compressor is made available to the building water circuit.

In certain applications the amount of heat reclaimed during occupied hours may exceed the daytime heating requirements of perimeter zones. This excess heat can be stored for release during times when the building is unoccupied.

The cost of installing a double-bundle condenser system is such that, in most cases, it probably will be most feasible as a replacement for a system which already is at or near the end of its useful life.

11.2 Energy Management And Control (EMC) Systems

An EMC system performs its function on systems. If it alters the operation of just one element of a system, the whole system still is affected. Accordingly, before any decision is made with regard to functions to be performed, the EMC system consultant must ascertain the types of functions which should be provided, and the specific manner in which these functions should be performed in light of characteristics unique to the building system involved, the purposes for which it is used, and the effect—if any—that applications of an EMC system will have on system performance and output.

Timing of EMC feasibility and design studies is important. It is generally recommended that EMC should be considered only after an initial energy management plan has been completed. Failure to consider nonEMC ECO's could result in failure to capitalize on major savings opportunities. For example, applying EMC to a given system may result in savings of X. By modifying the system first and then applying the EMC system, savings may amount to 2X. By the same token, modifying a system or replacing it may suggest that one type of EMC approach is better than another.

While many consultants can handle a building's general energy management needs, not all are well versed in EMC systems. As such, it may be appropriate to include an EMC specialist on an energy audit team, especially so if Level III EMC (discussed below) system is likely to be installed.

11.2.1 Types of EMC Systems

a. Level I: Localized Controllers

Level I systems provide independent, relatively low cost control for specified sytems and equipment. Each local controller is independent, controlling its specified operating system or equipment without acting in conjunction with any other controlling device. The initial cost of such devices is relatively low.

Level I controls consist of:

- Time clocks,
- local annunciators/alarms, and
- local optimization, for example, controlling dampers based on outside air temperature.

Level I systems usually are most applicable when:

- The control device is compatible with the system involved and will improve system operation and efficiency;
- usage and climatic factors permit;
- the HVAC systems involved are relatively simple;
- only a single small building with few mechanical equipment rooms is involved, or each building of a complex of buildings has a small, individual HVAC system;
- the capital budget is $1,000 or less;
- immediate results are desired, for example, because installation time allowable is minimal, and/or
- individual system or component optimization is more important than total systemwide optimization.

b. Level II: Remote Limited and Multifunction Controllers

Level II EMC systems are typified by a limited function demand controller which interfaces with numerous energy consuming devices and systems to limit electrical demand. Many of the newest Level II controllers are programmable through use of microprocessors, and provide for multifunction capability in the same "black box." The high value of savings which a multifunction demand-based controller can generate, coupled to low cost, make this type of control one of the most beneficial available.

Typical Level II EMC system functions include:

- Remote start/stop (turning systems and devices on at a certain time);
- optimized start/stop (based on outdoor and indoor temperature variances);
- status monitoring (Is it running or has it stopped?);
- status alarms (Is it operating outside of the normal range? Is it too high? Too low?);
- demand control, and
- duty cycling.

Level II systems usually are most applicable when:

- The capital budget is less than $20,000,
- the functions to be performed are limited, and
- the number of points to be monitored and controlled are generally less than 100.

Examples of Level II controllers are as follows:

i. **Demand Controller**
Electric utilities now use two different methods of controlling a user's kilowatt demand—fixed interval and sliding window. Some demand controllers are designed to control a user's demand over a continuous series of fixed time intervals, which may be 15, 30, or 60 minutes in duration. However, all start at a specific point in time and the end of one interval signals the start of the next.

Because the fixed-interval method made it possible for users to exceed peak-demand levels without additional cost by using high demand at the end of one interval and at the beginning of the next, electric utilities developed the sliding window concept. Some new types of controllers are designed for this rate-setting method. The sliding window has no specific start point. Therefore, the controller maintains demand control by constantly updating an interval start point and recalculating an average demand over the new, ever-changing interval.

Many of the new types of demand controllers can contend with present utility rate structures and metering methods and can be adjusted to changes that might be imposed by utilities.

ii. **Optimal Start Programmer**
An optimal start programmer starts HVAC equipment when it is actually needed. It compares outdoor and indoor air temperatures. The difference between the two indicates when the HVAC system must be started in order to meet conditions desired when the first building occupants arrive, or when the most heavily staffed shift begins. The logic system of the controller is preset to take the building envelope's heat transmission factor into consideration.

iii. **Multifunction Programmable Controller**
Multifunction controllers are microprocessor-based. Typically, they perform electrical demand control, load scheduling based

on time of day, optimized start/stop, and duty cycling.

Differences among off-the-shelf systems center on memory capacity, method of programming, input/output ratings, expansion capability and increments, readout options and methods used to accomplish end results.

c. Level III: Centralized Computerized Control

Level III EMC systems employ one or more computers to make control decisions based on operating data and programs, as well as data contained in memory.

Level III system functions include:

- Automatic start/stop,
- closed-loop refrigeration and boiler system control,
- status monitoring,
- status alarms,
- load shedding,
- duty cycling,
- data collection,
- enthalphy control,
- event initiation,
- utilities monitoring,
- maintenance management,
- monitoring and control of the building's life safety systems, and
- optimization of system operation to minimize energy consumption.

Level III systems are appropriate when:

- A capital budget of $200,000 or more is available,
- optimization functions are needed,
- control decisions are to be based on the number of parameters and conditions involved, and on the series of events which occur,
- operating and maintenance personnel who understand the system either are on-hand or will be hired,
- user programming capability is available,
- the facility comprises a high-rise building or a complex of buildings with a central plant and several remote mechanical equipment rooms, and
- there are 200 or more points.

Level III systems can be divided into two very general categories: packaged and hybrid.

A *packaged system* is one which is complete in every respect, furnished by a manufacturer who assumes sole responsibility.

A *hybrid system* is one which is composed of elements fabricated by several manufacturers. Depending on the nature of the contract, one vendor may assume sole responsibility for the entire system.

A packaged system, by its nature, is somewhat limited. If it does not satisfy all needs by design, very little can be done. A hybrid system can be designed to fit needs precisely, and very often can accomodate the very latest state-of-the-art components.

Several government agencies are now utilizing a "distributive processing" approach, meaning that functions normally performed solely by the system's central processing unit (CPU) are, in part, distributed among other system elements. In a distributed system, for example, field interface devices (FIDs) which serve various control and monitoring points in an area include microprocessors to handle various functions otherwise handled by the CPU.

Functions which cannot be handled by the "smart" FIDs are then passed on through the system's hierarchy. Instead of going to the CPU, however, they are fed to an intermediary device called a Central Communications Controller (CCC), in essence, a stripped-down minicomputer. Only those functions which cannot be handled by the CCC then are passed on to the CPU.

The principal benefit of the distributed concept is greatly enhanced system reliability, due to increased system redundancy. In the event that one element of a system is down for any reason, another element in most cases can take over for it. Distributed processing also makes it far easier and less expensive to accomodate expansion, be it for addition of new points or new functions.

11.2.2 EMC Functions and Applications

The following discussion relates primarily to Level III EMC systems. Nonetheless, the principles involved are applicable to all levels. Two other points deserve comment.

First, the functions discussed are limited primarily to energy conservation and systems optimization. Most EMC systems can also perform functions associated with building security, fire safety, and—in some cases—accounting and inventory.

Second, the functions indicated relate primarily to HVAC systems. Many can be applied to other systems, for example, remote start/stop for lighting systems.

a. Basic Functions

Basic functions are those which are generally applicable to a broad range of systems and equipment. Some of these functions include the following:

i. Timed Operation

Timed operations functions consist of starting and stopping a system based on the time (weekdays, Saturdays, etc.) of day. Timed operation provides the greatest potential for energy conservation if systems are currently being operated during unoccupied hours. It also is the simplest function to install, maintain, and operate.

ii. Duty Cycling

Duty cycling consists of shutting down a system for predetermined short periods of time during normal operating hours, such as 15 minutes of each hour of operation. The off period time length normally is increased during moderate seasons and reduced during peak seasons.

The subject of duty cycling has caused considerable controversy with regard to the damage which it may or may not cause to motors.

Studies suggest that few if any problems will be experienced when the motor involved is relatively small, that is, approximately 50 HP or less.

iii. Temperature-Compensated Duty Cycling

With temperature-compensated duty cycling, each load has a related space temperature data point assigned to it. Each load serving interior zones (cooling only) is cycled off for its assigned maximum period as temperature in the space drops to its assigned minimum value. Likewise, the interior load is cycled off for its assigned minimum period as space temperature rises to its assigned maximum value.

iv. Demand Control

Demand control function stops electrical loads to prevent a predetermined maximum electrical demand from being exceeded. Most of the systems employ logic which monitors the base electrical demand continuously and predicts whether or not the preset limit will be exceeded. If it will be, certain scheduled electrical loads (secondary loads) are shut off. Additional secondary loads are turned off on a priority basis if the initial load shed action does not reduce the predicted demand enough to satisfy the function requirements.

v. Outside Air Temperature Cutoff

With an outside air temperature cutoff, heating systems, except for direct-fired warm air systems smaller than 500,000 Btu per hour design input capacity, are provided with an outdoor temperature-sensing control which cuts off the heating system for all types of spaces when the outdoor temperature rises to within 5°F of the indoor design temperature, or to a minimum of 40°F.

vi. Warm-up/Night Cycle

The thermal load imposed by outside air used for ventilation may constitute a substantial percentage of the total heating and cooling requirements. The warm-up/night cycle function controls the outside air dampers when the introduction of outside air would impose a thermal load and the building is unoccupied.

vii. Space Temperature Night Setback

The energy required to maintain space conditions during the unoccupied hours can be reduced by lowering the temperature set point for the space, depending on the climatic conditions.

b. Optimizing Functions

Optimizing functions are those which improve the operating efficiency of a given piece of equipment or system by monitoring performance and performing adjustment on a real time basis. Typical optimizing functions include, but are not limited to the following:

i. Economizer Cycle

The economizer cycle utilizes outside air to satisfy all or a portion of the building's cooling requirements when the temperature (or total heat content) of the outside air is less than that of the return air from the space. Outside air is introduced through the mechanical system and relieved during this cycle instead of the normal recirculation system.

A *dry bulb (DB) economizer cycle* is regulated by an outdoor air temperature sensor which discontinues compressor operation when outdoor temperature falls below the design supply temperature, normally 50°F to 60°F.

An *enthalpy economizer cycle* is similar to a dry bulb economizer cycle, except it measures total heat content (enthalpy) of air. Outdoor air is used for cooling when its enthalpy is less than the enthalphy of return air.

ii. Hot/Cold Deck Temperature Reset

HVAC systems such as dual duct and multizone utilize a parallel arrangement of heating and cooling surfaces (hot and cold deck surfaces) to provide simultaneous heating and cooling. These systems are extremely wasteful, because the temperature settings of the hot and cold decks usually are fixed, typically at 90°F and 55°F, respectively. With temperature reset, the system selects the individual areas with the greatest heating and cooling requirements and adjusts hot and cold deck temperature accordingly, minimizing the inefficiency of the system by reducing the difference between hot and cold deck temperatures.

iii. Discharge Air Temperature Reset

The discharge air temperature reset function adjusts the cooling coil discharge temperature upward until the zone with greatest demand for cooling has closed its reheat coil valve.

iv. Chilled Water Reset

The energy required to generate chilled water in a reciprocating or centrifugal electric-driven refrigeration machine, is a function of a number of parameters including the temperature of the chilled water leaving the machine. Because the refrigerant suction temperature is a direct function of the leaving water temperature, the higher the two temperatures, the lower the energy input per ton of refrigeration. Since chilled water temperatures are selected for peak design times, most chilled water temperatures can be elevated during most operating hours, unless strict humidity control is required. Depending on several factors, energy can be saved by resetting the chilled water temperature, allowing it to rise to satisfy the greatest cooling requirements. Specific control schemes depend on system configuration.

v. Outside Air Schedule Reset

Water heating systems are designed to supply system heating requirements at outdoor design temperatures. Depending on the specific system design, the hot water supply temperature can be reduced as heating requirements are reduced, usually in response to increased outdoor ambient temperatures. Where applicable, the capability to reduce the temperature of the supply water as a function of outdoor temperature will effect operating savings. To accomplish this function, the temperature controller for the hot water supply is reset on a predetermined schedule as a function of outdoor temperature.

vi. Start/Stop Optimization

Mechanical systems which are shut down during unoccupied hours usually are restarted in accord with a fixed schedule, independent of weather or space conditions. Optimized start/stop starts and stops the system based on thermal inertia of a structure, the capacity of the system to either increase or reduce temperatures in the facility start-up and shut-down times, and weater conditions.

vii. Air Distribution Optimization

The air distribution function controls zone dampers to stop the flow of conditioned air to nonessential areas during unoccupied periods. Dampers (which in most cases will have to be installed) are positioned automatically by an optimum start/stop program. Supply fan dampers and associated exhaust fans are positioned by static pressure sensors.

viii. Chiller Plant Optimization

Chiller efficiency usually decreases with chiller load below 50 percent. When a multiple chiller installation is involved, therefore, it generally is desirable to load each chiller as much as possible. In other words, it generally would be better to have two chillers loaded equally, as opposed to having one loaded to 100% and another to 30%.

ix. Boiler Plant Optimization

Several techniques are available to accomplish the boiler plant optimization function, depending upon factors unique to the facility involved.

In one approach, electronic probes can be used to continually monitor the amount of O_2 (oxygen) that passes through the boiler plant stack. Data collected permits the CPU to determine heat losses associated with that stack. If the O_2 level is outside optimum limits, the CPU can initiate control to regulate air flow through the boiler and stack at constant firing rates, to bring the O_2 level within proper operating limits and retain maximum combustion efficiency.

Another method of boiler plant optimization involves decreasing the fuel flow to the boiler as load on the boiler decreases. During winter, higher outdoor air temperatures reduce building heat requirements, reducing the amount of heat the boiler has to produce. Boiler outlet water temperature can be reduced by mixing the outlet water with boiler inlet water, to create a mixture determined by the outside air temperature and the boiler water temperature difference. This unloads the boiler and decreases fuel consumption. As the boiler unloads, flue gas temperature decreases, but still remains high enough to not precipitate corrosive substances inside the boiler stack.

x. Secondary Loop Chilled/Hot Water Optimization

There usually are many secondary loops serving similar coils, each tied into the primary loop main distribution system. With optimization, the control valve adjusts coil capacity to meet load by modulating coil flow, or by changing the temperature of water to the coil. Whenever the valve lowers coil output, it indicates that full capacity of the supply water is not needed. Accordingly, secondary loop optimization logic is based on the premise that if no coils need full supply water capacity, supply water temperature can be adjusted to save energy, by raising chilled water temperature and lowering hot water temperature. This action also saves energy by reducing pipe heat gains and losses.

Dehumidification must be considered when chilled water is affected.

c. Operational Functions

Operational functions are primarily those which are associated with monitoring and alarm, as follows:

i. Chiller Profile Generation

Through a chiller profile generation function, the EMC systems develop a printed record of the operating status of the chiller equipment for a given set of conditions, such as load ambient conditions and time of day. The program accumulates chiller profile historical data required to evaluate efficiency and cost of operation.

ii. Boiler Profile Generation

The boiler profile records operating data of boiler plant equipment for a given set of conditions such as load, energy output, energy input and ambient conditions to determine operating costs and to accumulate historical data for the plant. When a sufficient number of profiles of the plant has been obtained, curves of the plant can be derived, plotting efficiency as a function of the operating characteristics. Curves thus derived become the basis of reference for optimization routines.

iii. Maintenance of Building Systems

An EMC system can be programmed (depending on the specific type system involved) to provide daily printouts of regular maintenance procedures which must be undertaken, together with as-needed notification of unscheduled maintenance procedures which may be required. There are several ways in which the maintenance scheduling functions can be handled, as follows:

- Calendar Time Scheduling: With calendar time scheduling, for example, every 20 days maintenance personnel could be instructed to change all air handling unit filters, or once-a-month instructions can be given to grease and lubricate certain equipment.
- Machine Running Time Scheduling: The CPU can be set to accumulate running time data of certain equipment and, after a predetermined number of running hours for each item, print out maintenance instructions.
- Efficiency Scheduling: In certain cases the amount of time equipment runs will not be an accurate indicator of its operating efficiency or need for maintenance. Since the CPU can calculate equipment operating efficiency on the basis of raw data inputs, it can be programmed to provide maintenance instructions when efficiency deteriorates to a certain predetermined level.
- Early Warning Monitor: The system can be designed to provide early warnings of impending equipment failure. As one example, bearings of certain pieces of equipment can be monitored for vibration and/or temperature. Should the vibration or temperature level increase to a certain predetermined level, a panel light, readout, etc., would indicate an immediate, unscheduled maintenance problem.

iv. Maintenance Cost Management Program

A maintenance cost management program stores maintenance costs and maintenance labor hours for individual units, fans, motors, pumps, etc.

v. Trouble Diagnosis

By monitoring certain parameters of the mechanical/electrical systems, diagnosis of reported problems with mechanical and electrical systems can be performed at the central console location. Some of the parameters that might be monitored include hot and cold deck temperature with high and low limits, leaving chilled water temperatures and hot water temperatures with high and low limits, differential pressure switches indicating fan and pump operation or excessive pressure losses through filters or condenser tube bundles, space temperatures, and improper humidifier operation.

vi. Safety Alarms

Many items of mechanical equipment are provided with various types of alarms for both personnel and equipment protection. High and low water for boilers, gas pressure, and temperature and pressure on refrigeration machines are typical of the types of functions that can be monitored. Monitoring of such alarms provides the console operator with information regarding the failure of equipment or the development of potential problems with the system operation.

vii. Intercom

The system can be used for intercommunication between maintenance personnel and console operators for a checkout of the overall system, and for monitoring of start-up of equipment.

d. Other Functions

Most Level III systems can be devised to provide functions which go beyond energy management alone, thus enhancing their cost-effectiveness. These functions relate primarily to security and fire safety.

i. Security

- Door Security and Control: Achieved by a signalling device for use by those wishing to gain entrance. An intercom can be used for the oerator to ascertain the identity of the person. If he is to be allowed in, the operator can activate an electromechanical device which releases the door. Closed circuit television and magnetically coded identification cards can be used to supplement or replace certain elements of this system.
- Intrusion Protection: Consists of monitoring devices attached to possible ingresses and connected to the central console. Typical devices are the familiar strips of metallic foil placed on window which activate an electric circuit if broken, as well as contact devices on doors; photo-electric beams; infrared beams; vibration detection devices; ultrasonic motion detectors; video motion detectors; microwave detectors (which sense disturbances in the electromagnetic field); electrical capacitance detectors (for small areas), and so on. Selected objects, such as file cabinets and vaults, can be fitted with devices which sense changes in electrical capacitance or vibration.
- Closed Circuit TV (CCTV) Security: CCTV cameras can be placed to monitor selected doors, isolated pedestrian tunnels, certain stairwells, large open areas (such as malls or parking lots), etc. The security or central console can have one viewer for each camera.
- Guard Communication: A transmitter-receiver can be built into the console for communication with guards carrying

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walkie-talkies, or the operator can signal guards to communicate by activating a pager carried, or the operator may contact the guard by means of activating a light at the guard tour station. Also, a guard can notify the operator of his position on his tour of duty by activating signals at each of his tour stations.

ii. Fire Detection

A centralized computerized control system is an invaluable asset for purposes of fire detection and alarm. The central processing unit can be designed to continuously monitor the entire building's fire detection and alarm network, including flame and smoke detectors, thermal fire detectors, firestats, sprinkler alarms, etc.

Any off-normal condition can be reported immediately, along with the type and location of the device triggered. Depending on the sophistication of the system, certain control functions can be implemented automatically, especially in the absence of an operator. Such functions could include notifying the nearest fire station of a problem, activation of sprinkler systems, activation of audible alarms, and even activation of selected pre-recorded tapes for building-wide transmission providing clear, distinct instructions, programmable so selected instructions are broadcast to the respective areas of the building to which they apply.

11.2.3 System Design and Specification

Numerous factors must be considered in designing and specifying a system which meets requirements. The following discussion highlights many of the specific factors involved:

a. Basic Selection Criteria

The basic criteria to consider in selecting a system are as follows:

i. Cost Effectiveness

Cost effectiveness is the basic criterion to be used in determining which level of EMC is best, and specifically what type of system or architecture will yield maximum return on investment. Cost effectiveness is determined through use of life-cycle costing techniques.

ii. Adaptability

How well a given system can be adapted to an existing facility is extremely important. Physical requirements of the new system are the most obvious of the adaptability concerns. In fact, will the system fit into the existing space? It is suggested that some 900 square feet are needed for the command center of an EMC system, and that location of the center should be considered strategically in light of the functions to be performed there. If the space is not readily available, can it be made available? If something must be displaced, will new construction be necessary? If so, of course, it must be considered in the economic analysis.

One must also consider existing local controls, or the possibility of installing local controls at this time, with the likelihood that Level III EMC system will be added at a later date. Can the EMC system be interfaced with these local controls, or will the controls have to be replaced?

Consider, too, the existing equipment. If much of the most costly mechanical equipment is scheduled for replacement, will the new equipment be compatible with the EMC system? Likewise, if the new equipment will be far more efficient than that which it replaces, is the EMC system needed, or could local controls suffice?

iii. Maintenance

The ability to maintain a system is extremely important. One of the related concerns involves the provider's ability to support in-house maintenance through training programs and manuals. Equally important, if not even more so, is the availability of professionally trained maintenance persons employed, licensed or authorized by the manufacturer.

Wherever possible, references should be checked to determine how satisfied other users of the proposed system are with the maintenance services provided. Key concerns in this regard are completeness of preventive maintenance, responsiveness and capability of outside maintenance crews, the annual cost of the maintenance (which usually is in the range of 8 — 12% of initial installed cost), and the availability of a service maintenance agreement.

Recognize that, without proper maintenance, the system will not perform reliably. In fact, this has been a critical problem with many Level III EMC system installations.

Maintainability should be considered in design. While a high level of sophistication may be desirable, increased sophistication often results in increased maintenance problems and costs. Trade-offs may be necessary.

iv. Reliability

Reliability relates to two issues.

The first issue is how well the system performs; information attainable from other users of the system.

The second issue is the way in which the system performs. In fact, some problems may be built in so that, for example, occasional interference with transmission lines results in signals that are not received properly or at all, erroneous data, etc.

v. Expandability

An existing system may not be suitable to handle additional points. Expansion may require the purchase of another computer, an additional memory and/or more and larger FIDs. It may cause programming inconvenience, high factory charges, and disruption of the normal operational routines. These problems can be minimized by looking ahead at the time of initial design. An allowance for future growth usually is advisable, especially from a cost standpoint. Points cost approximately $500 each at the time of initial installation; $1500-$2000 when added later (in 1979 dollars).

vi. Programmability

It is recommended strongly that the system be user-programmable. In this way, programs can be easily modified or added in the field as needed. Manufacturer-provided program revisions usually are very expensive.

b. Drawings

Once a system has been decided upon, drawings and specifications — the contract documents — must be prepared.

Drawings are extremely important. They must be reviewed carefully for completeness and accuracy, and should clearly and precisely indicate the designer's intent. It is also very important that the consultant carefully coordinate the drawings with the specifications in terms of the components' functions with respect to each other.

Many things should be included in a set of drawings. A few of the most important factors, basic to all EMC system packages, are:

- block diagram
- interconnecting trunk wiring data link diagram
- point schedule
- functional layout diagram
- system schematics diagram
- field interface panels diagram
- equipment modifications drawings, and
- existing control system and interface diagrams.

(Existing control system and interface diagrams are extremely important because they delineate where all the existing components are located. If, for example, the system is to perform motor start/stop, the contractor must know where the motor starter is located, what kind of starter it is, and what he must do to that starter to include it as part of the entire system. Everything must be shown explicitly, detailing what can be used, what must be replaced, and what must be added. Showing a box with an "X" in it, or just writing "Enthalphy Control" or "Provide on/off Auto Control" is not sufficient. Providing detail is necessary for bidder information, and to safeguard against a "blank check" situation caused by changed orders needed to correct problems resulting from lack of information.)

c. Specifications

Some of the major concerns which should be addressed in a specification are:

- degree of accuracy
- level of access
- use of existing controls
- electric power considerations
- factory debugging
- acceptance testing, and
- training

11.3 Solar Energy

Although solar energy systems have been given a great deal of publicity, their applications are limited. Nonetheless, with the cost of energy escalating as it is, solar applications are becoming realistic energy management options. As such, they deserve some investigation, especially so if federal or other government funding is available to help offset installation costs.

11.3.1 Typical Solar Energy Systems and Components

Systems for converting solar energy into useful thermal energy for space heating, cooling, or heating of service hot water can be classified as either *active* or *passive*.

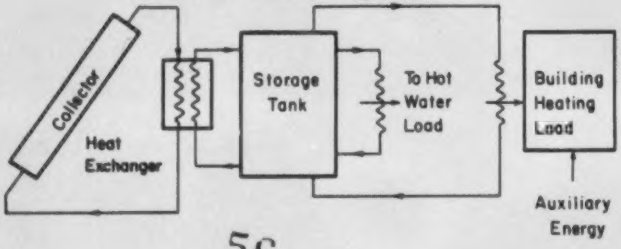
In an *active system*, the flow of thermal energy into the building is controlled through the use of auxiliary equipment such as pumps, valves, and heat exchangers.

In *passive* solar systems, the energy flow is automatic, requiring little or no auxiliary equipment. In most of the passive systems, either a south wall or a flat roof is designed so that the structural unit (or a part of it) collects and stores the thermal energy. Examples are a massive concrete wall, painted black and covered with a transparent surface, or stationary roof ponds/water beds covered with movable insulation. Experiments have been conducted on these systems and similar concepts. It appears that they are the most promising from an economical viewpoint in certain regions of the country. In almost all cases, however, the passive system must be designed as an integral part of the building. Therefore, *only the active systems* usually can be added into existing buildings.

Figure VI-2 is a schematic representation of an active solar space heating and service water heating system. A fluid is

FIG VI-2

Schematic diagram of a liquid solar heating and service water heating system



pumped through a solar collector. Solar radiation heats the fluid. The thermal energy is transferred to a storage unit through a heat exchanger. The resulting storage energy is transferred through additional heat exchangers either to heat service water or to heat the building space. The system can be made more complicated by the inclusion of additional equipment that would also use the thermal energy in the storage tank to provide either space cooling or space heating by some other means than through the heat exchangers, as shown.

Methods of using the thermal energy to provide space cooling include the use of absorption and Rankine-cycle refrigeration units. In the absorption units, the energy from thermal storage is used as a heat source to boil refrigerant from a solution. The refrigerant subsequently absorbs energy from the space to be cooled. In the Rankine-cycle units, the thermal energy is used to drive a heat engine which is coupled to a conventional vapor-compression-cycle refrigeration unit. Systems for solar cooling have been put into operation, but in general, they are even less competitive with conventional equipment (on an economic basis) than either solar service water heating or space heating.

An alternate method of providing space heating using solar energy is to integrate a heat pump into the system. This can be done in several ways, and can involve air-to-air, air-to-water, or water-to-water vapor-compression-cycle heat pumps. If the building is heated entirely by the heat pump and the source side of the heat pump is exclusively the thermal storage unit, it is called a "solar-boosted" heat pump. If a more flexible yet more complicated system is employed, where a heat exchanger is used along with the heat pump, and the source side of the heat pump can be either the thermal storage unit of the outside air, depending upon operating conditions, the system is designated as a "solar-assisted" heat pump.

a. Active Solar Systems

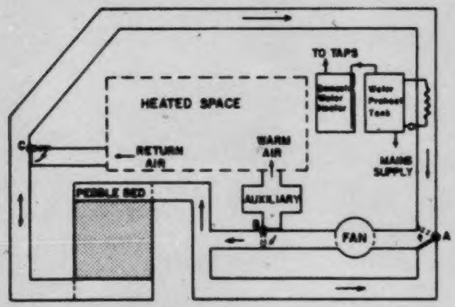
The types of active solar systems commercially available today are divided into those which use a water antifreeze solution as the basic heat transfer fluid, and those which use air.

Systems which use a water antifreeze solution are configured basically as shown in Figure VI-2. The storage unit is usually one or more large water tanks. The heat exchanger between the collector and storage tank could be eliminated if the system were located in an area where freezing would not occur, or if provisions were made to drain the solar collector at night. There is usually a pump in each loop of the system and the pumps are controlled depending upon the available solar radiation and the demand for either hot water or space heating within the building. A special case of this system is one which only heats service water.

Figure VI-3 shows a schematic diagram of a system that uses air as the basic working fluid. Only one fan is used; the air flow is through ducts, and it is controlled and directed to the various components through the use of motorized dampers. For example, when solar energy is available for collection and there is a space heating load, room-temperature air is drawn through the solar collectors, heated, and returned to the building. When solar energy is available for collection and there is no space heating load, air is drawn from the bottom of the storage unit (which is most often a packed bed of rocks or pebble bed), heated and returned to the top of the storage unit. When there is a space heating load and no solar energy can be collected, hot air is drawn from the top of the pebble bed and blown into the house while room temperature air is returned to the bottom of the pebble bed. In contrast to the water-system, there is no need for a heat exchanger between the collector and the storage unit and between the storage unit and the building space. An air-to-water heat exchanger is usually used for heating and service water.

FIG VI-3

Schematic diagram of a solar air heating and domestic hot water system



In both systems, the auxiliary energy source for both space heating and service water heating would, in most cases, be the conventional equipment now installed. The components would be compatible with almost any type of energy distribution system installed in the existing buildings; however, depending upon the type of installed system, one might tend to select specific types of solar components. For example, an installation system using radiators or fan-coil units for space heating would be more compatible with a water-type system than with one using air collectors.

The primary consideration in comparing air vs. liquid systems involves their life cycle costs.

Although complete information on total installed costs of liquid and air systems are not yet definitive, there do not appear to be large differences. Since both use only small amounts of auxiliary energy for circulating fluids and have comparable overall thermal efficiencies, the major differences appear to be in durability and maintenance. Since the air system is permanently dry, no significant corrosion of the collector absorber occurs. There is no possibility of freezing the collector fluid, because decomposable antifreeze compounds or other organic liquids are not required. Boiling cannot occur, so replacement of collector fluid is never needed. Fluid leakage, although not precluded, involves minimal corrective cost and no secondary damage. Some long-term operating experience with an air system shows that maintenance is not a significant expense and that the equipment can be expected to have a life comparable to that of the building itself.

b. Solar Collectors

The cross-section of a typical flat-plate solar collector used to heat a liquid is shown in Figure VI-4. It consists of a darkened metal absorbing plate that the fluid passes over or through one or two sheets of some transparent material on the top through which the solar energy passes, and several inches of insulation on the back. The transparent cover and the insulation both serve to reduce heat loss from the metal absorbing plate and to maximize the amount of the energy being carried away by the fluid. The collector is usually facing south (±20°) and tilted at an angle designed to optimize the amount of solar energy received over a complete heating season.

Typical metal absorbing plates are made of copper, aluminum, and steel. Generally speaking, copper is preferred for liquid systems, because of its superior corrosion resistance and durability. Copper is expensive and usually is heavy, so aluminum has been used a great deal over the past several years. It affords relatively low cost, light weight, and ease of fabrication. Use of aluminum absorbers in a liquid system required special precautions to prevent corrosion. Steel has had some limited use because of its low cost, but it is heavy, difficult to fabricate, and — like aluminum — requires corrosion protection. Plastics have been used in isolated cases, but usually only for relatively low temperature applications such as heating swimming pools.

Materials for air collectors are selected primarily on the basis of cost, because there are no corrosion factors to consider. Figure VI-5 shows the cross-section of three different types of air collectors.

The primary source of energy loss from the solar collector is convection and radiation heat transfer from the top of the absorber to the cover plate and subsequent heat transfer away to the environment. A variety of techniques are used to limit this heat loss. The use of double glazing is the most straightforward and widely used technique. It can reduce the heat loss by as much as 40% to 50% when the collector is operating at a temperature as high as 190°F above the ambient, and when the absorber is painted with an ordinary black paint. Other techniques include the use of a selective coating on the absorber to reduce re-radiation; a transparent honeycomb insert between the absorber and the cover plate assembly to limit air motion and decrease convection heat transfer; some form of concentrator incorporated into the design to concentrate the energy onto the absorber; evacuating the space between the absorber and the cover-plate assembly to eliminate convection altogether; or some combination of the above. The collectors being built today, which have an evacuated space, usually are of tubular construction. The absorber is a metal or glass tube and the cover plate is a glass cylinder surrounding the absorber.

FIG VI-4

Schematic diagram of flat-plate liquid-heating solar collector

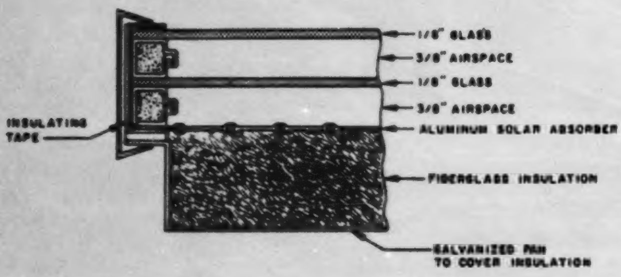
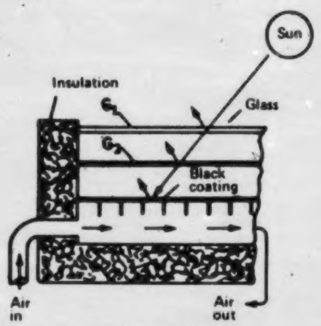
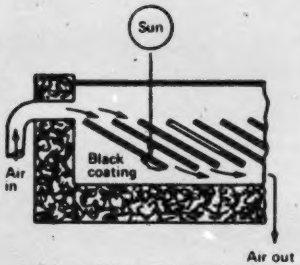


FIG VI-5

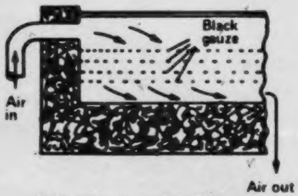
Different types of collectors



Solar collector with double-glazed finned absorber plate



Solar collector with single-glazed, overlapping glass plate



Solar collector with single-glazed, porous absorber

Although some very encouraging results have been obtained in the last few years in the solar collector field, it is very difficult to economically justify any collector other than the simple single- or double-glazed flat-plate collector for service water heating or space heating. Most of the new designs result in significant increases in efficiency at the high temperatures required for air conditioning (190-240°F); however, the improvement at the lower operating temperatures for service water heating and space heating (120-150°F) in most cases cannot justify the additional investment.

c. Thermal Storage Components

The majority of all systems built to date have used either water tanks or pebble beds for storing thermal energy. Water tanks have been used primarily in systems employing water heating collectors; pebble beds with air collectors.

The primary reasons are proven reliability, low cost, and ease of installation and maintenance. Other methods of storing thermal energy that have been proposed are being used primarily in research and demonstration projects. These involve the use of materials which absorb significant amounts of energy upon change of phase and consequently result in much greater energy storage per unit volume than through the use of water or rocks. The major work in recent years has involved the use of paraffins and eutectic mixtures of salts and salt hydrates.

d. Service Water Heating Systems

Except for heating swimming pool water, the heating of service water with solar energy is the most economically viable application and the one that can be considered for all locations within the United States. There are several reasons for this. One is the low capital cost relative to solar space heating or cooling systems and the others relate to the unique characteristics of service water heating.

The demand for hot water is relatively constant throughout the year. This means that the collector and other parts of the system produce energy for long periods of time and consequently can result in large savings that eventually must pay for the higher intial cost of the system. This is in contrast to a solar space heating system which is fully operational only during the coldest months of the heating season.

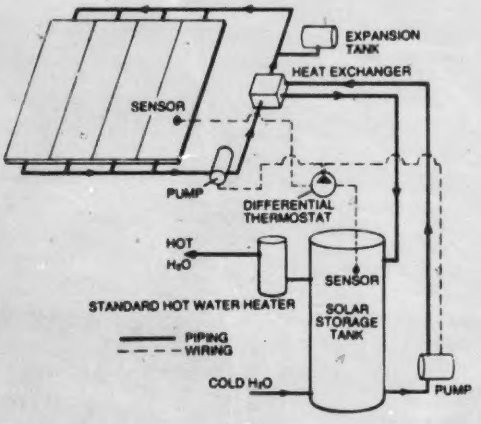
A solar service water heating system can also be sized more closely to the demand. While space heating systems have to handle extreme loads only a few days of the year, they still have to be sized large enough (including the auxiliary back-up) to meet those extremes. A service water heating system, on the other hand, will have roughly the same load, day in and day out. Except in unusual applications, the design load (expected maximum load) will be close to the normal daily load. By avoiding the problems of widely fluctuating loads, the solar service water heating systems can be much more economical.

A problem common to all types of solar heating is the variable nature of sunshine. Solar water heaters, however, can often have an additional advantage over space heating systems because the requirements for hot water are less rigid than those for space heating. If there is an extended period of cloud cover and the user is extremely conscious of energy and cost savings, some uses of hot water can be temporarily postponed. This, of course, is not desirable with space heating systems.

Figure VI-6 shows a schematic of a typical system. The collector, pumps, and heat exchanger are used to heat water which is stored in a tank. This water, in turn, is fed to the existing service water heating system, which only has to make up the difference between the incoming water temperature from the solar storage tank and the constant supply temperature to the user. The controls in such a system are very much simpler than those required by most solar space heating systems. The thermostat in the already existing heater controls the auxiliary energy supply, as always. The only other controls needed are the sensor and differential thermostat shown to turn the pumps on and off.

FIG VI-6

Schematic diagram of a solar domestic hot water system



For normal hot water use, approximately one square foot of collector per one gallon of hot water used per day usually is adequate. If kitchens or other processes require hot water at elevated temperatures. collector area required is from 25% to 50% more. The solar collector can be mounted on the main roof, the roof of a building extension, or on-site. Although each installation must be considered a unique subsystem, the following solar collector installation guidelines should be considered:

i. Provide adequate structural support to carry the dead weight (12 lbs./sq. ft.) of the collector plus wind loading.

ii. Orient the collector 10° west of due south if possible, but 20° either side of due south will not materially affect the performance. If the orientation must be farther to the east or west, plan on additional collector area.

iii. If the collector is used solely to supply hot water, a fixed tilt of latitude plus 20° will usually be optimum—variations of 10° up or down will not seriously affect yearly performance.

iv. Collector must not be shaded more than 10% of the time, or a larger collector area will be required.

v. Provide approximately one square foot of collector and one gallon of hot water storage capacity per 16 gallons of hot water used per week. If kitchens or other processes require hot water at elevated temperature, provide one square foot of collector per 20 gallons of hot water used per year.

vi. The existing domestic hot water heating system, even though inefficient or undersized will usually be adequate to provide heat to supplement the solar collector system.

e. Space Heating and Cooling

Prior to 1972, only about twenty solar heated buildings were erected in the United States. Of those, only one was a commercial building. Since 1972 there has been a proliferation of solar energy activity in the United States, for both new buildings and existing buildings.

The hardware for solar space heating and cooling includes solar collectors, piping, controls and storage systems which are similar to those used for domestic hot water heating, but with the following major differences:

- The required collector area and storage volumes must be larger and are most costly.
- Collectors must produce hotter water temperatures for space heating. Temperatures up to 180°F are desirable, but lower temperatures can be used.
- The orientation of the collector is more critical.
- Absorber plates with selective surfaces rather than flat black coating are be more economically feasible for heating and cooling applications than for solar water heating alone.
- Interface with existing heating and/or cooling system is critical.
- Storage systems must have a greater heat storage capacity per square foot of collector.
- Rocks or phase changing salts can be used for thermal storage instead of water in some cases.
- Collectors can be air instead of liquid heating types in selected applications.
- A full sized back-up heating system is required to supplement the solar system.

In most areas of the country for most buildings the cost of a solar energy system to provide 100% of the heating and/or cooling is prohibitive. These systems can be used to supplement more conventional systems however. Because the extremely limited applicability of solar energy to supplement heating and cooling systems of existing buildings at this time — due primarily to cost, space and structural requirements — no further discussion is provided herein.

VII. FINANCIAL EVALUATION AND COMPLETING THE PLAN

Once the various energy dollar conservation options have been identified, the next step is developing an action plan. In addition to identifying the various ECOs that will be implemented, the plan also must detail when ECOs will be implemented and by whom. The plan also should include methods for monitoring results of the energy management program, checking utility bills, and keeping building users informed of progress.

An effective plan details every single action associated with conduct of the energy management program. It also is dynamic in nature, allowing for changes based on experience.

The heart of the plan relates to the specific energy management options to be used. In most cases, numerous options will be identified, perhaps enough for three or more years of activity. Clearly, a method is needed to rank the options in terms of priority, to identify which should be implemented first, which second, and so on, making sure that none of the options conflicts with others. The financial aspects of the various options typically form the basis for assigning priorities. Management must know how much implementing an option will cost, and how much it will save. Management can then evaluate an option much as any other investment opportunity would be evaluated.

1. ECONOMIC EVALUATION

Management usually applies several tests to any prospective investment to determine if it is worthwhile. Some of these tests are classic, such as simple payback period analysis, discounted payback analysis, and savings-to-investment ratio (SIR). Other tests are variations of textbook approaches, developed to meet criteria established by any specific management group.

The following discussion examines classic textbook approaches which, in almost all cases, are the basis for economic evaluation. Once they are learned it takes little effort to adjust them for the specific reporting method preferred.

1.1 Simple Payback Period

Simple payback period is the easiest of all economic factors to calculate. It identifies the amount of time required for the savings generated by an option to equal the cost of implementing the option. Expressed as a formula:

$$\text{Simple Payback} = \frac{\text{Initial Cost}}{\text{Annual Savings}}$$

Example:

It will cost $1,500 to install a demand controller which will save $700 per year. What is the simple payback period?

$$\text{Simple Payback Period} = \frac{\$1{,}500}{\$700} = 2.14 \text{ years}$$

To convert an annual figure such as 2.14 years into months, weeks, or days, just multiply by the appropriate factor:

$2.14 \text{ years} \times 12 \text{ months/year} = 25.7 \text{ months}$
$2.14 \text{ years} \times 52 \text{ weeks/year} = 111.3 \text{ weeks}$
$2.14 \text{ years} \times 365 \text{ days/year} = 781.1 \text{ days}$

Simple payback period analysis has many uses, but all of them are limited, because too many questions remain unanswered. For example, assume that you are trying to decide between two types of energy management controls. They cost the same, but Control A pays back in two years and has a usable life of ten years, while Control B pays back in three years, but has a usable life of 15 years. Which is the better buy? Simple payback analysis does not provide the answer.

Simple payback also fails to consider the time value of money, the impact of inflation, or differential escalation (the difference between the general rate of inflation and the higher rate of inflation expected to affect energy prices in general).

Simple payback period analysis should be used primarily to obtain a *very general idea* about the cost-effectiveness of a given option. Other methods of analysis then are used for the more in-depth study that usually is required. The other methods used fall within the broad concept called *life cycle costing*, or LCC.

1.2 Life Cycle Costing

Life cycle costing provides the major benefit of considering all costs of a product, device or system that accumulate over its useful life. Typical costs include those to purchase, install, maintain, and operate, among others. By using LCC techniques, it may be shown that a product which is twice as expensive as another actually may be only half as expensive on a life-cycle basis.

Specific elements of LCC can be applied for different purposes, as to determine:

- Whether it is better to repair an old item or replace it with a new one.
- Which of two or more similar items is less expensive over the life cycle.
- Which of two similar energy-saving systems, such as different types of insulation, will be the most cost-effective (best buy for the money spent).
- Which of two dissimilar energy conservation measures is the best investment, give a limited budget.

a. Basic Concepts of LCC

Successful application of life cycle costing techniques requires an understanding of the basic concepts they entail, as follows:

i. Economic Life

The economic life of equipment or materials is either its expected useful life, or the amount of time for which it will be used — whichever is shorter. If the building will be torn down in 15 years, however, the boiler's economic life is 15 years.

ii. Initial Capital Investment

Initial capital investment refers to the net amount of your investment, including selling price, sales tax, delivery charges, and installation costs. When the new investment replaces an older one, the old one possibly could be sold as used equipment or for scrap. In most cases, however, it will have no value, and you may have to include the cost of carting it away.

Tax factors also should be considered. For example, installation of insulation or solar water heating equipment may entitle you to a tax credit. If so, determine how much it will be and deduct it from the capital investment cost.

iii. Maintenance Cost

Two kinds of maintenance costs should be considered. The first is routine maintenance, such as cleaning, oiling, and tightening. The second involves replacement of components which wear out, such as filters and drive belts. Determine the maintenance requirements of the item being considered. If they are highly technical, will in-house maintenance personnel be able to maintain them, or will a service maintenance contract be needed? In either case, what will be the maintenance costs?

iv. Annual Energy Consumption and Saving: Cost and Value

Annual energy consumption is the amount of energy used by equipment or an appliance each year.

Annual energy savings represent the amount of energy saved each year by implementing an ECO, such as installing storm windows. Energy savings also indicate the difference between two similar energy-consuming items. For example, if item A consumes 1,300 kWh per year, and item B consumes 1,680 kWh, item A provides annual energy savings of 380 kWh.

The annual cost of consumption and the annual value of savings are determined by multiplying the amount of energy involved by the cost per energy unit: kWh of electricity, 1,000 cubic feet (MCF) of gas, gallons of oil or pounds of steam.

b. Present Value of Savings

Money is a commodity. When people take out a loan, they are leasing or renting money. The interest paid is the lease or rental charge.

Many commercial enterprises usually obtain a 10 percent annual return on capital, or more, through any one of several different investment alternatives. These investment alternatives are called the "standard investment." Obviously, it would be unwise to invest in anything that returns less than the standard investment.

Table VII-1.
Annual and Cumulative Present Value Factors at 10%

Years	Annual Factors	Accumulative Factor
1	0.9091	0.9091
2	0.8264	1.7355
3	0.7513	2.4868
4	0.6830	3.1698
5	0.6209	3.7907
6	0.5645	4.3552
7	0.5132	4.8684
8	0.4665	5.3349
9	0.4241	5.7590
10	0.3855	6.1445
11	0.3505	6.4950
12	0.3187	6.8137
13	0.2897	7.1034
14	0.2633	7.3667
15	0.2394	7.6061
16	0.2176	7.8238
17	0.1979	8.0216
18	0.1798	8.2014
19	0.1635	8.3649
20	0.1486	8.5135
21	0.1351	8.6486
22	0.1229	8.7715
23	0.1117	8.8832
24	0.1015	8.9847
25	0.0923	9.0770

The method used to determine whether or not a given investment is better than the standard investment is called present worth analysis. Present worth analysis is based on the concept that a dollar received today is worth more than a dollar received at some time in the future.

Assuming that the standard investment yields a 10% return, a dollar invested today will be worth $1.10 ($1.00 + ($1.00 × 10%) or $1.00 × 1.10) at the end of one year. Accordingly, $1.10 received one year from now has a present worth of $1.00 ($1.10 ÷ 1.10). Likewise, $1 received one year from now has a present worth of $0.9091 ($1.00 ÷ 1.10) because $0.9091 applied to the standard investment will be worth $1.00 in one year. $1.00 received two years from now has a present worth of only $0.826 (1.00 ÷ 1.10 ÷ 1.10), and $1.00 received three years from now has a present worth of $0.751 (1.00 ÷ 1.10 ÷ 1.10 ÷ 1.10).

When the standard investment rate is applied in reverse to find the present worth of money to be received in the future, it is called the discount rate. It has many different uses, but one of the most significant is to compare the present worth of future energy dollar savings with the investment required to obtain those savings. This puts both financial calculations on the same time-period basis, since the investment will have to be made with today's dollars. If $1,000 is required to implement an energy option which will generate savings over its economic life with a present worth of $990, clearly the investment would not be a good one.

Tables of present worth factors are included in almost any book on engineering economics. Most of these tables provide two columns of factors. One column provides factors needed to determine the present value of $1 received one year from now, or two years from now, or ten years from now, etc. The other column provides *cumulative values*, that is, the present worth of receiving $1.00 per year for the next three years, the next four years, etc. Table VII-1 is typical. It uses 10% as the discount rate. As can be seen, $1.00 received ten years from now has a present worth of $0.3855 ($1.00 × 10 year annual factor of 0.3855). $5.00 received ten years from now has a present worth of $1.9275 ($5.00 × 0.3855). $1.00 received annually for ten years would have a present worth of $6.1445 ($1.00 × 10 year cumulative factor of 6.1445). $5.00 received annually for ten years would have a present worth of $30.7225 (5.00 × 6.1445).

c. Savings-to-investment Ratio (SIR)

Savings-to-investment ratio or SIR, is also spoken of as benefit/cost ratio. An SIR compares the present worth of savings to be obtained over an energy management investment's economic life, to what it costs today to make that investment. Thus, if it costs $10 to buy a device that will generate savings with a present worth of $9.09, it is not a wise investment because the benefit-to-cost, or savings-to-investment ratio is less than 1:

$$\frac{\text{Benefit (Savings)}}{\text{Cost (Investment)}} = \frac{\$\ 9.09}{\$10.00} = .909$$

To determine the SIR of a device which costs $550, and which will save $75 per year for 15 years, refer to the cumulative column of Table VII-1. The 15-year cumulative factor of 7.6061 is multiplied by $75 to obtain $570.46, the cumulative present worth of $75/year received for 15 successive years. The benefit/cost or savings/investment ratio is:

$$\frac{\$570.46}{\$\ 550} = 1.0372$$

Table VII-2.
SIR CONVERSION TABLE

SIR	5 YEARS	10 YEARS	15 YEARS	20 YEARS	25 YEARS
1.0	5.00	10.00	15.00	20.00	25.00
1.1	4.43	8.58	12.34	15.60	18.30
1.2	3.98	7.53	10.54	12.97	14.82
1.3	3.62	6.71	9.23	11.16	12.57
1.4	3.31	6.06	8.22	9.83	10.97
1.5	3.06	5.53	7.42	8.80	9.75
1.6	2.84	5.08	6.77	7.97	8.79
1.7	2.65	4.71	6.22	7.29	8.01
1.8	2.48	4.38	5.76	6.72	7.36
1.9	2.33	4.10	5.37	6.24	6.82
2.0	2.20	3.85	5.02	5.82	6.35
2.1	2.09	3.63	4.72	5.45	5.94
2.2	1.98	3.44	4.45	5.13	5.58
2.3	1.89	3.26	4.21	4.85	5.27
2.4	1.80	3.10	4.00	4.60	4.99
2.5	1.73	2.96	3.81	4.37	4.73
2.6	1.66	2.83	3.63	4.16	4.51
2.7	1.59	3.71	3.47	3.97	4.30
2.8	1.53	2.60	3.33	3.80	4.11
2.9	1.47	2.50	3.19	3.65	3.94
3.0	1.42	2.40	3.07	3.50	3.78
3.1	1.37	2.32	2.95	3.37	3.63
3.2	1.32	2.24	2.85	3.24	3.50
3.3	1.28	2.16	2.75	3.13	3.37
3.4	1.24	2.09	2.66	3.02	3.26
3.5	1.20	2.03	2.57	2.92	3.15
3.6	1.17	1.96	2.49	2.83	3.05
3.7	1.13	1.91	2.41	2.74	2.95
3.8	1.10	1.85	2.34	2.66	2.86
3.9	1.07	1.80	2.28	2.58	2.78
4.0	1.04	1.75	2.21	2.51	2.70
4.5	.92	1.54	1.92	2.20	2.36
5.0	.83	1.38	1.73	1.96	2.10
5.5	.75	1.24	1.56	1.76	1.89
6.0	.68	1.13	1.42	1.61	1.72
6.5	.63	1.04	1.31	1.47	1.58
7.0	.58	.96	1.21	1.36	1.46
7.5	.54	.90	1.12	1.26	1.35
8.0	.51	.84	1.05	1.18	1.26
8.5	.48	.79	.98	1.11	1.18
9.0	.45	.74	.93	1.04	1.12
9.5	.43	.70	.88	.99	1.05
10.0	.41	.67	.83	.93	1.00

*To be used for evaluation procedures using nomograph. This conversion table is not valid when considering energy cost escalation.

Source: "Life Cycle Costing Emphasizing Energy Conservation," Energy Research and Development Administration, (Department of Energy), May 1977.

Since the SIR exceeds 1, the value of the savings exceeds what would be earned if $550 were invested at 10% interest for 15 years.

As another example, consider two different options, option A and option B, both with 15-year economic lives. Option A costs $750 and will save $130 annually. Option B costs $1,250 and will save $175 annually. The better investment is determined as follows:

Option A
Benefit = $130 × 7.6061 = $988.79
Cost = $750
Benefit/Cost Ratio = 1.32

Option B
Benefit = $175 × 7.6061 = $1,331.07
Cost = $1,250
Benefit/Cost Ratio = 1.06

Although both investments are good, option A is far superior.

d. Discounted Payback Period

As already discussed, the use of simple payback period analysis is limited because it fails to consider the time value of money. Discounted payback does consider the time value of money. It is determined by using the nomograph shown in Figure VII-1.

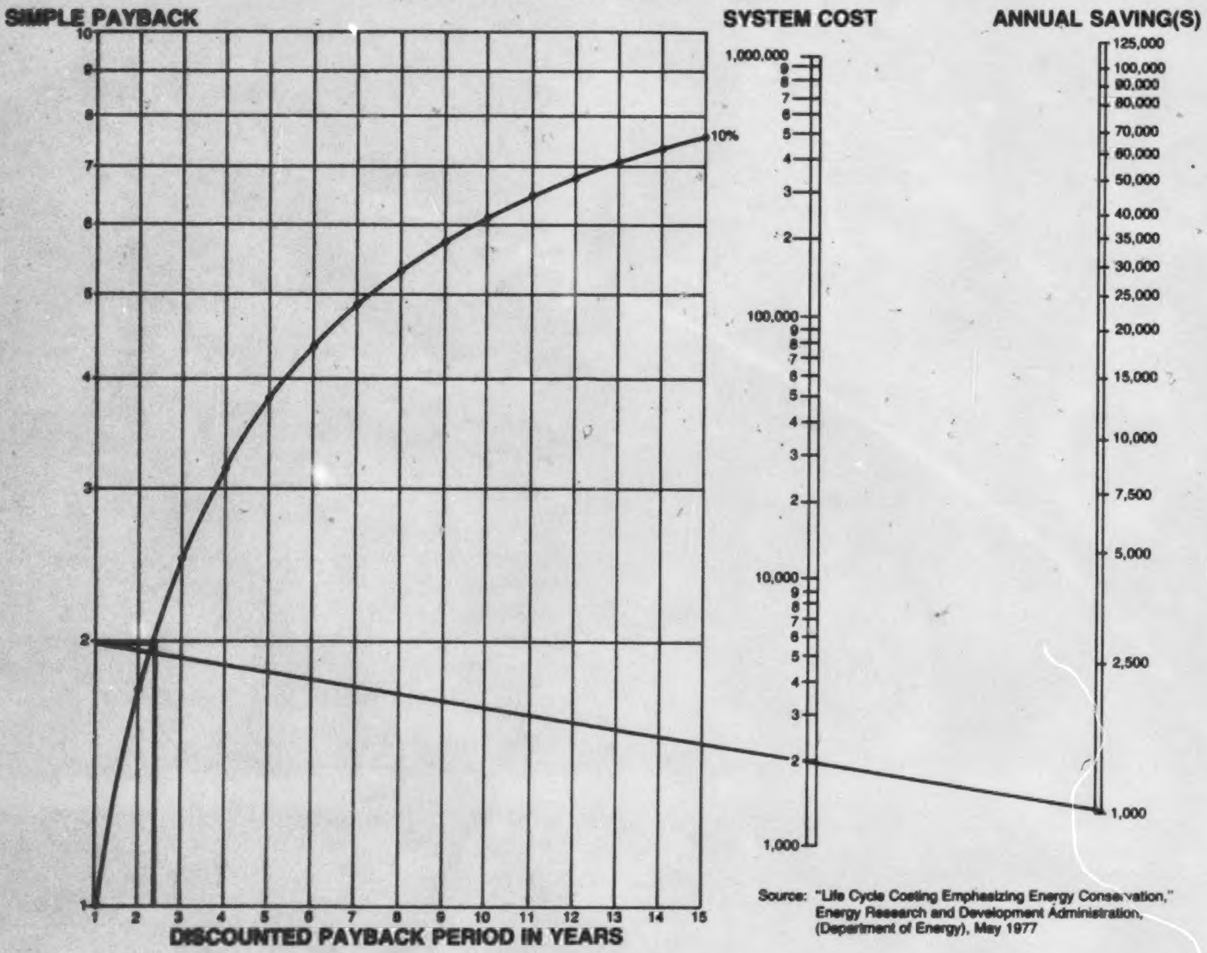
To use the nomograph, plot the appropriate two points under the *annual savings* and *system cost* columns. Draw a straight line from right to left until it intersects the simple payback axis (far left). Draw a horizontal line to the right of this point of intersections, until the line intersects the 10% curve. Simple payback is indicated where the line intersects the simple payback axis. Discounted payback is found by reading straight downward from that point where the line intersects the 10% curve.

The example investment shown in Figure VII-1 involves annual savings of $1,000 and initial costs of $2,000. As such, simple payback is two years and discounted payback is 2.37 years.

Table VII-2 can be used to find the benefit/cost or savings/investment ratio of the example investment. Assuming that it has a 10-year economic life, enter the table at the 10-years column, and read down until you find the factor closest to the discounted payback period computed from the nomograph; in this case, 2.37 is 2.40. Reading across to the left, you find under the SIR column that the savings/investment ratio is 3.0. The SIR of 3.0 means that the investment is a good one, since it is far more than 1.

Table VII-2 can also be used to determine the discounted payback of an investment when the SIR is

Figure VII.1
Discounted Payback Period Nomograph



Source: "Life Cycle Costing Emphasizing Energy Conservation," Energy Research and Development Administration, (Department of Energy), May 1977 known. For example, if the SIR is 1.48 and the economic life of the investment is 15 years, read down the SIR column to find the factor closest to 1.48, which would be 1.5. Reading over to the right, under the 15-year column, find the factor 7.42. This means that the discounted payback of that particular investment is 7.42 years, or 7 years and 5 months (.42 × 12 months = 5.04 months).

Note that both the nomograph and Table VII-2 should be used for initial analysis only. They are not valid when energy cost escalation is considered. Other texts should be consulted for tables and nomographs for discount rates other than 10%. Building management probably can obtain these texts for you.

e. Differential Evaluation

Inflation is another factor which requires analysis before making an investment.

Inflation refers to generally increasing costs or, stated another way, the shrinking value of the dollar. If someone is paid $15,000 per year for five years without a raise, inflation makes the salary worth continually less because of the rising costs of goods and services.

The rising cost of goods and services is measured by the U.S. Department of Commerce in terms of the consumer price index, or CPI. As the cost of the goods and services increases, the CPI increases. If a $15,000 annual salary was tied into the CPI so that it increased every time the CPI increased, at the end of five years the salary would exceed $23,000 per year, assuming an annual inflation rate of 9%. Even though the salary grows by that much, however, it still will be worth no more than what it was in the beginning, because it still can buy only the same amount of goods and services.

When analyzing long-term costs and savings, you do not have to allow for inflation if you assume that the costs of all goods and services will increase at about the same rate. In fact, it can be assumed that the costs of most goods and services will continue to increase at about the same general rate of inflation. However, there is good reason to believe that the cost of energy will increase at a rate which exceeds the general rate of inflation. If this occurs, the value of energy savings will increase and the related discounted payback periods will decline. Table VII-3 provides the factors required to calculate cumulative present value factors for various differential escalation rates. A differential rate of 3% means that the cost of energy will increase at a rate of 3% more than the general rate of inflation each year.

1.3 Applying Life Cycle Costing to ECOs

Once you have developed a list of options that can be exercised in your building, perform the appropriate type of economic analysis for each, with two exceptions.

First, do not bother analyzing "no-cost" or "low-cost" options whose savings are extremely difficult to calculate. As already discussed, it would be wasteful to determine the savings obtained by caulking around three windows. The value of the time required to perform the calculations is likely to exceed the cost of making the repairs.

Table VII-3.
Accumulative Present Value Factor of 10% Differential Escalation Rates

Year	1%	2%	3%	4%	5%
1	0.9182	0.9273	0.9364	0.9455	0.9546
2	1.7612	1.7871	1.8131	1.8393	1.8657
3	2.5353	2.5844	2.6340	2.6844	2.7354
4	3.2460	3.3237	3.4027	3.4834	3.5656
5	3.8986	4.0092	4.1225	4.2388	4.3581
6	4.4978	4.6449	4.7966	4.9531	5.1146
7	5.0480	5.2344	5.4278	5.6284	5.8367
8	5.5521	5.7810	6.0188	6.2669	6.5260
9	6.0159	6.2878	6.5722	6.8705	7.1839
10	6.4417	6.7577	7.0903	7.4411	7.8118
11	6.8328	7.1935	7.5755	7.9807	8.4113
12	7.1919	7.5977	8.0299	8.4909	8.9837
13	7.5216	7.9725	8.4553	8.9733	9.5300
14	7.8243	8.3199	8.8536	9.4293	10.0513
15	8.1022	8.6421	9.2266	9.8604	10.5490
16	8.3574	8.9408	9.5758	10.2680	11.0240
17	8.5918	9.2179	9.9029	10.6535	11.4776
18	8.8069	9.4747	10.2090	11.0177	11.9103
19	9.0044	9.7129	10.4957	11.3622	12.3235
20	9.1857	9.9337	10.7641	11.6878	12.7178
21	9.3512	10.1385	11.0154	11.9957	13.0942
22	9.5042	10.3285	11.2509	12.2870	13.4537
23	9.6446	10.5046	11.4714	12.5623	13.7968
24	9.7735	10.6679	11.6777	12.8225	14.1241
25	9.8919	10.8193	11.8710	13.0686	14.4367

Second, do not attempt to provide LCC evaluations of modifications which will require a feasiblity analysis. For example, if you find that a heat reclamation system is applicable, it will take a comprehensive study to determine which particular type of heat reclamation system is most applicable, as well as the specific models which are best. It is completely acceptable to indicate some estimated LCC figures, which would be needed in subsequent steps of finalizing the energy management plan. Outside assistance may be needed to obtain these estimates. Given what has been discussed already, initial cost and annual savings estimates collected from two or three manufacturers' representatives should be sufficient for you to make reasonable LCC estimates on your own.

2. SETTING PRIORITIES FOR OPTIONS

Once appropriate economic factors are calculated for each ECO, all ECOs can be assigned a priority to determine which should be performed first, which second, and so on.

It is impossible to tell you what your priorities should be because only you know the criteria which must be used as the basis for establishing them.

In terms of energy conservation, perhaps the most logical approach is to give top consideration to those factors which relate to areas of high energy use. Using a 1-to-5 rating scale, where 5 represents the greatest potential for savings, the following generalized listing can be established:

- **Ventilation (5)**
- **External Heat Gain and Heat Loss (Solar Radiation, Wind, etc.) (4)**
- **Light System (4)**
- **Heating and Cooling System (3)**
- **Transmission Heat Gain and Heat Loss (2)**
- **Domestic Hot Water (1)**
- **Power System (1)**
- **Internal Heat Gains (Business Equipment, People, etc.) (1)**

In most cases, the financial analysis performed on each ECO will indicate where maximum savings are to be obtained. However, more than cost factors may be important. In some cases, an ECO which is more cost-effective than another may not save as much energy, or may not save as much of a particular type of energy, such as gas or oil.

The following steps are suggested to develop an effective priority process:

2.1 Review Interrelationships

The first step in setting priorities requires evaluation of ECOs in terms of interrelationships. Obviously it would be counterproductive to implement an ECO in February only to have to "undo" it in November. For example, there would be no point in relamping to high-efficiency fluorescent lamps if fluorescent luminaires will soon be replaced for conversion to high-pressure sodium lighting.

More than ECOs should be considered. For example, if a new east wing will be added to the building, it probably would be wasteful to reglaze all existing windows on what is now the east facade. For reasons such as this, management personnel should also be involved in setting priorities.

Analyzing interrelationships should include identification of ECOs that should be implemented at the same time. For example, if there are three ventilation system ECOs, it may be best to implement them all at once. To implement the ECOs sequentially could mean far greater expense, since systemwide adjustments may be needed after each is complete. Implementing all three together would mean that systemwide adjustments would be performed only once.

Analyzing interrelationships may also indicate that one particular version of a device is better than another. For example, if energy and dollars will be saved through installation of equipment for demand control, remote start/stop, duty cycling, and optimal start/stop, you could install devices for each function, one at a time, over a period of two or three years. Alternatively, you could obtain just one device to perform all four functions, and install it now, to increase your savings.

2.2 Establish Priorities

Once interrelationships are established, certain general priorities also become known. For example, some ECOs should be implemented before others to reduce expense; some should be performed at the same time to reduce expense, and some should not be implemented now because implementation of a more comprehensive ECO later will increase overall benefits to be obtained.

Once general priorities are identified, specific priorities can be evaluated in terms of cost and benefits.

In most cases, it is practical to concentrate on the most effective low/no cost ECOs during the first year, and then handle the less effective low cost/no cost ECO steps in subsequent years. Several moderate cost ECOs also could be implemented the first year, with more in the second year, and less later on. Options requiring substantial investment could be started during the second year, once those involved have gained good experience.

Initial emphasis usually is placed on remedial maintenance; bringing devices up to design conditions unless slated for immediate replacement or substantial modification. In some cases, the improved efficiency resulting from remedial maintenance may suggest that a proposed ECO should be changed.

Initial attention also should be given to equipment which is at the end of its usefulness. Even though major cost is involved such equipment should be replaced immediately, if only to improve deteriorated comfort conditions, or to comply with codes. Note that replacements should be energy efficient, and should be selected in light of related changes that will be made. In some cases, making a replacement may make a reordering of other priorities appropriate.

Major changes which are likely to affect the building also must be considered. In some cases, as already discussed, such changes may suggest that certain ECOs should not be implemented. In other cases, however, a major change of some type may make feasible a modification which otherwise could not be economically justified.

Major space usage changes also may influence priorities. For example, if a general office space will soon be converted for use by drafting personnel, far more lighting may be needed. If so, modification of the existing lighting system would be an immediate concern. If a new tenant intends to operate on a 16-hour, two-shift day, the impact on virtually all building systems would have to be assessed. A reordering of priorities may be the result.

One also must consider the amount of investment capital available.

Management assistance may be needed to identify strategies to derive maximum utility from the budget. One of these strategies may involve leasing, so capital expense is minimized.

Recognize, too, that some basic concerns may take priority over all others. These relate to the persons who will be doing much of the work. In some cases, it will be best to commence the majority of the energy management retrofit options only after in-house staff has received some additional training and/or after maintenance and operating routines and methods have been improved.

The factors used to evaluate the priority of any given option will be unique to the specific building or facility involved. By having operating and management personnel on the energy management team, most of the key factors will be identified and discussed.

3. CREATING THE PLAN

Once priorities are set for the various ECOs, it will be relatively simple to develop the initial energy management plan.

It is suggested that the plan be developed for a five-year period. For the first 18 months of action, specific details should be shown, that is, exactly which options are to be implemented and when. For months 19-60, details would be more general, to be made more specific with time. In that way, after the first six months, specific details would be added to months 19-24.

The ordering of ECO implementation should be reviewed closely to assure that it is reasonable, that is, that there will be enough people on hand to implement ECOs and take care of other, more routine matters.

The initial preliminary plan should be examined in terms of cost. In fact, will all the ECOs identified for implementation during months 1-12 stay within budget? Chances are some trial and error will be required for development of a preliminary plan.

After the preliminary plan is complete, it should be reviewed with top management. Once the necessary modifications are made, the plan then becomes final.

4. SETTING GOALS

Goals are essential to help assure that those involved with implementing the plan have a common "cause." The primary goal is set in terms of energy savings. The simplest method of setting this goal is to examine the plan itself. By totalling the savings to be realized from implementing the different ECOs, a goal is created. However, three important concerns must be observed.

First, consider when ECOs will be implemented. Savings usually are stated in annual terms. Thus, an ECO projected to save 50,000 kWh per year will save less than that amount during the year in which it is implemented, unless it is in place on January 1. Consider, too, the nature of the system and the way it is to be used. A cooling system modification may save nothing at all during the year in which it is implemented if the cooling system will not be used for the balance of the year.

Second, it generally is best to make goals attainable, to prevent the frustration of being unable to meet a goal which was set too high to begin with. By the same token, it would be unwise to set a goal too low, since early achievement of it could result in a "slackening off."

Third, remember when informing people of how well goals are being achieved to make appropriate adjustments for climatic and other variables which affect energy consumption.

There are many other goals which can be set. One of these relates to cost savings. In such cases the plan can be used to identify total projected cost savings for a given period. Changing energy rates must be considered for comparison purposes, along with the impact of climatic and other variables.

VIII. IMPLEMENTING THE FINAL PLAN

Once the energy management plan is final it is ready to be implemented. In fact, implementation itself is a concern worthy of being planned, to help assure that each function is assigned to a person who can handle it well, in terms of capability and time available. Some of the basic concerns are as follows.

1. INITIAL MANAGEMENT EFFORTS

Initial management efforts required for the TEM approach are not dissimilar from other initial organizational steps which must be undertaken when establishing a new venture.

First, determine what specifically is to be done to effect energy conservation. This includes allocation of resources (manpower, money, etc.), development of policies and procedures to be followed, assignment of specific accountable responsibilities, obtaining cooperation of operating personnel and tenants, determining what changes need to be made to operating and maintenance procedures and schedules, noting which equipment is to be repaired, adjusted or replaced, and so on.

Second, determine precisely what must be done to effect each change, in terms of meetings, hiring additional personnel, ordering materials, etc.

Third, determine the approximate amount of time which will be involved to effect each objective. For example, if signs must be printed, you may have to allow one week for preparation and approval of copy and graphics; two weeks for printing; one week for distribution, and three or four days for posting.

Fourth, determine when certain objectives must be completed. When you do this, of course, you automatically will determine when work on the objective should be started by using data obtained through the third step, above.

Fifth, prepare a master schedule which shows exactly what will be happening. Assign competent personnel to the various functions. Examine what you have prepared for possible conflicts, such as having someone scheduled to do something during the week he is on vacation, etc. Reschedule to avoid conflicts.

Do not expect everything to run smoothly. There are bound to be problems; schedules not met; people who fail to do what they were supposed to , etc. By having a master schedule, however, you will be able to make adjustments relatively easily. As time moves on, you also will be able to develop even more specific monthly schedules, most of which will contain routine procedures refined through experience.

2. OBTAINING PERSONNEL COOPERATION

Methods for obtaining cooperation of personnel already have been discussed to an extent in chapter III of this manual. It cannot be emphasized enough, however, that all personnel involved must be reminded of the tremendous contribution they can make to the overall program. In working with specific individuals, however, you may have to gear your approach to the personality of the person involved. We will not get into the subject of interpersonal relationships to any depth because numerous other works on the subject are available. In most cases, however, you will find that some minor planning of the way in which you approach an individual will help you obtain his cooperation. If at all possible, initial contact and occasional continuing contact should be made in person. Follow-up contact can be made by telephone. If the individual involved is doing a good job, he should be told so either in person or by telephone, with any congratulatory remarks to be followed at least by a personal letter. Initial cooperation seldom will be gained by showing a person a survey report and saying something to the effect of, "Joe, this report shows me that you've been doing a lousy job." The approach almost always is more effective when the negative focus is thing — rather than person — oriented. In other words, given a survey report which indicates poor performance of maintenance operations, one could say, "Joe, this report shows that the equipment is not in very good shape. We just can't afford to replace it so, we're going to be relying on you to help us with the repairs and keep it in top-notch condition." In fact, experience has shown that maintenance and operating functions generally are carried out in a less-than-effective manner. This often is due not so much to the quality of labor, but rather to lack of knowledge of specific system and equipment capabilities; performance characteristics, and operating, maintenance and control procedures. In many cases, for example, a maintenance person or operating engineer will carry out a function in a certain way because "that's the way the guy before me explained it," and "the guy before" got it from the one before him, and so on, each providing instruction perhaps in a one- or two-day period, with each instruction being subject to faults of memory. Therefore, to obtain full cooperation from personnel, and to help them turn their willingness to be of assistance into positive action, determine how they perform their functions now and where specific instruction is needed. Guidance is available from numerous sources: equipment manufacturers who can provide operating and maintenance manuals; pertinent publications and magazines; various manufacturer- and supplier-sponsored courses; continuing education programs of local colleges and universities; specific training by a consulting engineering firm or by a contractor specializing in the type equipment involved; contractor- or engineer-prepared operating and maintenance instructions if none can be obtained elsewhere; specific maintenance schedules which spell out exactly what must be done and when, etc. Simply put, you can obtain a lot more cooperation from a person if he is not being frustrated by the fact that he does not have the specific tools and knowledge required to achieve the goals you set.

3. OBTAINING TENANT COOPERATION

Obtaining cooperation from tenants was only discussed briefly in Chapter III because little is required through performance of a survey and related steps. In actual implementation, however, tenant cooperation can be of significant benefit. At the least you will want tenants to cooperate to the point of permitting entrance for routine inspection purposes. Greater understanding will be required to obtain their cooperation in matters such as turning off equipment and lighting when not in use, closing securely all doors leading to the exterior, and related matters which involve, primarily, correction of wasteful habits. Even more effort will be required to obtain cooperation when certain operating changes are made or requested, such as lowering the thermostat during the heating season and raising it during the cooling season; requesting that stairways are used for one flight trips or having the elevator stop on alternate floors only, turning off water fountains, etc.

If in the past you have communicated with tenants only to tell them to stop doing something which should not be done or to inform them of a rent increase, obviously it will be more difficult to obtain cooperation now.

It is suggested that you first establish which changes will involve tenants, either directly or indirectly. Once established, examine the different type leases in force to determine exactly who has the final say in certain matters, and perhaps who will bear the expense. So armed, meet or have a representative meet with whomever is in charge of each leased area. If feasible, present specific data relating to energy and operating costs of the building involved. Begin discussion with an explanation of the changes, expected energy cost increases and what your organization is preparing to do. Emphasize that many of the undertakings will require tenant cooperation. Identify each change which will affect tenants and explain what type effect is involved. In certain cases, of course, you will have to be prepared to negotiate changes. Try to be as flexible as possible, especially when the items concerned are of relatively low priority. Where items are important, however, try to be as firm as possible. Under no circumstances should you merely send a letter stating that a given change will be made (whether the tenant likes it or not) and that the tenant can help by doing thus and so. Personal contact is essential. An explanation of what is being done is essential.

If possible and practical, encourage the office managers to inform all employees of the impending changes and the way in which they can be of help. This, too, can be done best through personal contact, although, given the numbers probably involved, a joint meeting of one type or another will have to suffice. To prevent misinterpretation, you may request to be allowed to address the meeting yourself. In either case, materials should be prepared for distribution to employees. A typical letter-memorandum is shown below.

You will find that the use of signage, as mentioned throughout this manual, also will be of assistance. Signs such as PLEASE BE SURE DOOR IS CLOSED SECURELY. PLEASE TURN OFF THIS LIGHT WHEN ROOM IS NOT IN USE. DID YOU REMEMBER TO TURN OFF THE LIGHT? DO YOU REALLY HAVE TO USE THE ELEVATOR, OR CAN YOU USE THE EXERCISE? PLEASE DO NOT TAMPER WITH CONTROLS. WE ALL NEED TO SAVE ENERGY., and so on, placed in strategic locations, can be most helpful.

Maintain continuing contact and involve tenants in the team effort just as you include building personnel. Let them know that their efforts and cooperation are paying off, if just by placing an easel and sign in the lobby indicating monthly energy consumption data as compared to previous periods as part of "OPERATION CONSERVATION" or whatever other title you may wish to give your overall program to help develop an esprit de corps.

MEMORANDUM (EXAMPLE)

TO: EMPLOYEES, JONES, SMITH & ASSOCIATES

FROM: JOHN DOE, XYZ MANAGEMENT

RE: "OPERATION CONSERVATION"

As you no doubt are aware, we are in the midst of a national program to conserve energy. The goal is to make our country independent in terms of energy supplies. Because of this fact, and due to the skyrocketing costs of energy, XYZ Management has embarked on its own program called "OPERATION CONSERVATION." To make it a success, we need your cooperation and assistance.

Here are some of the specific things we'll be doing which will affect you in one way or another.

Temperature

We will be lowering the temperature to 65°F during the winter and raising it to 78°F during the summer. To compensate, wear a sweater or other warm clothing during the heating season. Wear light clothing during the cooling season.

Humidity

Because of changes being made in our air conditioning system, it may at times become a bit humid inside. We don't expect that it will happen to any great extent however.

Lighting

We will be removing lamps from certain lighting fixtures; moving others, and disconnecting some completely. Although the lighting levels will not be as high as they were before, the quality of lighting provided will be perfectly adequate for the type work being performed in the various areas affected. Of course, if you find that lighting for some reason is not adequate for your desk, please call maintenance and we'll make all necessary adjustments.

Elevators

We have eight elevators in the building. Three of them will be stopping at even-numbered floors only; three at odd-numbered floors only, and two will not be affected. This means that you may on occasion have to walk up or down a flight of stairs. It's an inconvenience, we know, but at least it will help us get the exercise we need.

We'll probably be making some other changes, too, and you'll be kept abreast of them. In the meantime, there are a few things you can do that will help us out a great deal. In many cases, we'll have signs around to remind you, too.

1. Turn off electrical equipment when not in use, such as desk lamps, typewriters, coffee pots, and so on. Certain equipment can only be turned off at the end of the day, though, but please be sure you do turn it off, especially the copying machines.
2. Turn on lights only when they're needed. Turn them off when they're not needed. While life of fluorescent lamps is reduced when they're turned off and on more frequently, the energy they use when they're on is wasted and doesn't make leaving them on worthwhile.
3. Please be sure that you close all windows and doors leading to unconditioned areas whenever the building's heating and cooling system is working. The less heat and cooling that's wasted, the more energy that's saved.
4. Whenever you can, group your errands together so you don't have to use the elevators as much. Do four things on one floor while you're there rather than making four separate trips. If possible, use the stairs instead of the elevator.
5. Please do not tamper with the thermostat. It has been carefully adjusted and calibrated.
6. Please report any leaky faucets, piping, valves etc., to the maintenance department.
7. Please close the blinds and drapes when the air conditioning is running during the day. It wastes lot of energy to have to cool down the sun. During the winter, though, open the blinds and drapes on the sunny side of the building during the day. The extra heat can be used, so can the extra light.
8. Send us your ideas and suggestions. We'll all benefit by saving energy.

We'll be keeping you posted on a month-by-month basis telling you how we're doing. We're trying to reach a goal of a 20% reduction in energy use this year and, with your help and patience, we think we can do it.

4. MONITORING YOUR PROGRAM AND KEEPING IT EFFECTIVE

Monitoring your program involves two distinct types of effort.

The first type effort consists of monitoring changes implemented in terms of the quality of implementation. If maintenance schedules are revised, for example, you should check with maintenance personnel to ensure they can handle the revised schedule. Check on equipment being maintained to ensure that maintenance is being performed well. In essence, this is doing nothing more than following procedures of good management — making sure that those responsible for carrying out specific functions carry them out in the most effective manner.

All changes implemented should be noted on an energy conservation log. Duplicate copies of operating and maintenance manuals and schedules and related information also should be kept on file should replacement become necessary. The same holds for cost and inspection records.

The second type effort concerns monitoring the effectiveness of the program itself in terms of energy consumption. This can be done easiest through use of the Energy Management Form discussed in Section IV. This form will provide information on the entire system and on certain subsystems if the subsystem involved is the only subsystem which utilizes a certain form of energy. For example, if coal is used only for heating purposes, amount of energy utilized for heating can be determined exactly by referring to coal consumption records. In most cases, however, subsystem information cannot be extracted easily from the Energy Management Form, nor is there any great need that subsystem information be determined precisely. If, however, you do feel that it is imperative to determine exactly how much energy specific subsystems, such as lighting, elevators, heating, cooling etc., consume, such information can be obtained either through check metering or conduct of an empirical survey.

Check metering involves actual metering of power being supplied by the various electrical feeders to the subsystems thereby establishing how much energy each subsystem utilizes.In more contemporary buildings, where individual subsystems are supplied power independently, such metering is a relatively simple undertaking. For older buildings, however, which typically have several systems operating from one feeder, the task is far more difficult, if not practically impossible. Even when contemporary buildings are involved, however, the cost of check metering — although as mentioned a relatively simple task — can be very high.

The alternative to check metering is an empirical survey wherein a professional is retained to survey the building and its various subsystems to establish data on all connected loads, their usage and load factors, to determine subsystem energy consumption. The larger the building involved, the more difficult and expensive the task becomes. Nonetheless, such work has and is being done. For example, one owner in the Philadelphia study revealed that he had retained a firm to undertake such work. Once data is on hand, he intends to allot to the various tenants an energy budget. Per lease agreement, each tenant would be "entitled" to a given amount of energy based on the loads used by the tenant included with the cost of rent. Any energy utilized above the stipulated amount would be paid for by the tenant. This same approach, of course, could be utilized through metering.

In either case, investment in subsystem monitoring will result in ability to know which systems utilize energy; the ability to recapture energy costs or a portion of them from tenants and, as such, an added incentive for tenants to cooperate in a program of energy conservation. While expense is involved, the exact amount required can be determined only through preliminary investigation with responsible firms. In some cases, the payback period may be short enought to warrant immediate adoption of such an approach.

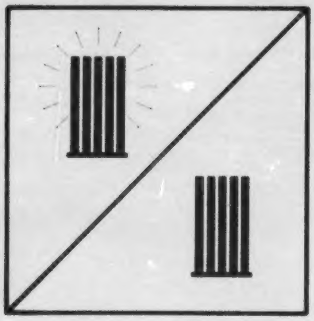
In certain cases — when a building is heated and cooled by electricity — energy utilized by heating and cooling subsystems is obtained easily by installing and monitoring separate, totalized and general load meters. Data obtained from several small office buildings included in the Philadelphia study which had electric heating/cooling systems, and which utilized such meters, indicate that overall energy consumption can be categorized as:

base load (lighting, equipment, elevators, etc.)	66%
space heating	14%
cooling	20%

The monitoring process, and the information which results from it, should be utilized to keep your TEM program as effective as possible by making improvements where data suggests improvement can be made; by undertaking alternatives which have not as yet been attempted; by revising goals where revision seems warranted, etc. In addition, it is suggested that the program be made as permanent a part of the building management function as possible. This effort would include holding periodic meetings with building and management personnel to keep them abreast of accomplishments, set-backs, future planning, and so on, as well as to request information and ideas which would benefit the program. Tenants should be treated in a similar manner to help ensure their involvement with the program and their continued willingness to make those efforts required to achieve conservation of energy.

5. CONTINUING EDUCATION

Since the field of energy conservation and Total Energy Management are relatively new, it is to be expected that the months ahead will result in development of many new products and techniques and geared for conservation of energy. Obviously, it will be to your own advantage to keep as much abreast of these developments as possible. For this reason it is suggested that you keep in close touch with appropriate national, state and local organizations as well as the various publications which relate to these fields. A listing of such organizations can be found in Appendix B.



CASE
IX. HISTORIES

Following are two case histories each providing details on the building involved, the nature of energy conservation activities undertaken, and the results of the effort based on comparison of consumption patterns for the same period in the previous year. As can be seen, several of the guidelines mentioned in the manual have been utilized to effect substantial savings achieved on a purely voluntary basis.

BUILDING A

LOCATION:	Philadelphia, Pennsylvania
TYPE:	Office
BUILDING CONDITION:	Modernized, kept up-to-date
AREA:	556,000 gross square feet
TYPE OF HVAC SYSTEM:	1400-ton central plus 300-ton packaged
NUMBER OF FLOORS:	19
BUILT:	1926
ENERGY SOURCES:	Electricity and purchased steam for cooling and heating.
AVERAGE OCCUPANCY:	98%
HOURS OF DAILY OCCUPANCY:	7:45 AM-5:15 PM

Energy Conservation Measures

Owner/manager established energy conservation measures in November 1973. These measures consisted of, among other things:

1. Setting thermostats at 68°F during the heating season.
2. Steam to noncritical building areas reduced.
3. Temperature of hot air decks in equipment rooms reduced.
4. Use of supplemental heaters banned.
5. Obstructions removed from perimeter heating units.
6. Serving cold lunch one day per week to reduce steam consumption.
7. Domestic hot water temperature reduced.
8. Reduction of lighting levels by an average of 50% in noncritical areas (e.g., restrooms, elevators, elevator lobbies, corridors, decorative lighting in lobby).
9. Lighting turned off in areas not in use (e.g., conference rooms, supply rooms, vacant offices, unoccupied space).
10. Exterior building lights turned off.
11. Employees encouraged to turn on lights only an area at a time as needed; to turn out lights when leaving a space for 20 minutes or more, and turn off lights near the end of the day.
12. Lights not used on Christmas tree ornamentation.
13. Venetian blinds and drapes closed during cold, windy days to provide additional insulation.
14. Sterilization of drinking water discontinued.
15. More efficient oven installed in kitchen.

Results of the program for the periods indicated are as follows:

	ELECTRICITY (KWH)			STEAM (MLBS)		
Month	**1972/1973**	**1973/1974**	**% Savings**	**1972/1973**	**1973/1974**	**% Savings**
DEC	573,656	477,000	16.8%	2945	1806	38.7%
JAN	644,028	506,000	28.1	4200	3794	9.7
FEB	567,000	474,000	16.4	3120	2987	4.3
MARCH	595,440	506,000	15.0	3664	2455	33.0
			Av. 17.5%			Av. 20.7%

BUILDING B

LOCATION:	Philadelphia, Pennsylvania
TYPE:	Office
BUILDING CONDITION:	Modernized
AREA:	574,000 gross square feet
TYPE OF HVAC SYSTEM:	1800-ton central plus 80-ton package
NUMBER OF FLOORS:	17
BUILT:	1912 (Addition 1932)
ENERGY SOURCES:	Electricity, purchased steam and natural gas for cooling and heating.
AVERAGE OCCUPANCY;	95-98%
HOURS OF DAILY OCCUPANCY:	8:30 AM-4:30 PM

Energy Conservation Measures

Owner/manager established conservation measures in September 1973. These measures consisted of, among other things:

1. Building thermostats set to 75°F during cooling season.
2. Outside air intake dampers set to minimum position.
3. Lowered temperature of domestic hot water.
4. Lighting levels reduced in corridors, wardrobes, washrooms and unoccupied areas by delamping of fluorescent fixtures, and relamping with "energy saver lamps."
5. Certain fluorescent lamps in office areas replaced by "energy saver lamps."
6. Operating schedules modified.
7. Elevator service reduced during off-peak hours.
8. Cleaning hours changed from 10 PM-6:30 AM to 4 PM-12:30 AM.
9. Lighting levels reduced during cleaning hours.

As can be seen, electricity consumption for the period January-May 1974 was 4% less than for the same period one year earlier. Steam consumption was reduced 8.6%.

Results of the program for the period indicated are as follows:

	ELECTRICITY (KWH)			STEAM (MLBS)		
Month	**1973**	**1974**	**% Savings**	**1973**	**1974**	**% Savings**
JAN	1,012,000	996,000	1.6%	3747.9	3530.0	5.8%
FEB	1,062,000	1,067,000	(.5%)	4273.8	4120.3	3.6%
MAR	1,016,000	922,000	9.3%	2728.9	2668.4	2.2%
APR	980,000	924,000	5.7%	2232.9	1631.8	26.9%
MAY	1,006,000	962,000	4.4%	1679.6	1455.1	13.4%

APPENDIX A

BUILDING INFORMATION
FOR
TOTAL ENERGY MANAGEMENT

GENERAL INFORMATION

Surveyed by: ____________________

Survey Date: ____________________

IDENTITY:

Name of building ____________________

Address ____________________

Primary Building Use ____________________

____

Person(s) in charge of building ____________________

____

PHYSICAL DATA:

Length, Feet and Orientation ______ Ft. N. W. E. S.

Width, Feet and Orientation ______ Ft. N. W. E. S.

Number of floors: ______

Height from floor to floor ______

Height from floor to ceiling ______

Floor area, gross conditioned square feet ____________________

____

Floor area, special use:

____________________ Ft^2 Computer Facility

____________________ Ft^2 Cafeteria

____________________ Ft^2 Bank

____________________ Ft^2 Other (describe)

____

____

____

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WINDOWS:

Type: ______ Fixed sash; ______ double hung; ______ casement

Glazing:

Exposure	No.	[1] Type	Gross Area	% Glass/Exterior wall area
N				
S				
E				
W				

[1] Type: Single, double, insulating, reflective, etc.

Glass shading employed outside (check one):

Fins ______ Overhead ______ None ______ Other ______

Glass shading employed inside (check one):

Shades ______ Blinds ______ Drapes, open mesh ______

Drapes opaque ______ None ______ Other ______

DOORS:

Door types and numbers:

1-single; 2-vestibule; 3-revolving

North – No. ______ Type ______ West – No. ______ Type ______

East – No. ______ Type ______ South – No. ______ Type ______

WALLS:

Orientation	Gross Wall Area	Net Wall Area
North		
South		
West		
East		

Exterior opaque wall construction: Circle Type:

1-frame; 2-curtain wall; 3-solid masonry; 4- brick and masonry; 5-masonry cavity

Exterior opaque wall insulation: Material: ______________

Thickness: ______________ U Value ______________

FLOOR:

Floor Construction: Circle Type: 1-slab on grade; 2-over heated space;

3-over unheated space; 4-wood; 5-concrete; 6-other

ROOF:

Roof Construction: Circle Type: 1-masonry; 2-wood; 3-metal; 4-flat;

5-sloped; 6-pitched; 7-light; 8-dark

Roof/Ceiling Insulation: Type: ________ Thickness: ______________

"U" Value: ______________

AIR LEAKAGE (check as appropriate):

Structural damage (through the wall/ceiling cracks) ______________________________

Broken or defective windows ______________________________

Ventilation exhaust that remain open all the time ______________________________

____

Tightness around windows and doors ______________________________

____

Note other major observed air leaks ______________________________

____

____

____

____

____

____

SKETCH OF BUILDING SHOWING PRINCIPAL DIMENSIONS AND ORIENTATION

BUILDING OCCUPANCY AND USE

	Weekdays		Saturdays		Sundays, Holidays	
	No. Of Occupants	Period of Occupancy	No. Of Occupants	Period of Occupancy	No. Of Occupants	Period of Occupancy
Administrative						
Custodial Operation						
Cafeteria						
Stores						
Banks						
Computer Operation						
Others (Describe)						
____________________						
____________________						
____________________						

MAINTAINED INDOOR ENVIRONMENTAL CONDITIONS

	Occupied hours				Unoccupied hours			
	Temp (^{o}F)		Rel. Humidity (%)		Temp (^{o}F)		Rel. Humidity (%)	
	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
Administrative Areas								
Computer Rooms								
Store Areas								
____________________								
____________________								
____________________								

SYSTEMS AND EQUIPMENT DATA
HVAC SYSTEMS:

a. AIR HANDLING SYSTEMS (check as appropriate):

Perimeter system designation:

Single zone ______ Multizone ______

Fan coil ______ Induction ______

Variable air volume ______ Dual duct ______

Terminal reheat ______ Self-contained ______

Heat pump ______

Interior system designation:

Fan coil ______ Variable air volume ______

Single zone ______ Other (describe) ______

Principle of operation:
Perimeter:

Heating-cooling-off ______

Air volume variation ______

Air mixing control ______

Temperature variation ______

Interior:

Heating-cooling-off ______

Air volume variation ______

Temperature variation ______

b. VENTILATION:

1. Minimum Outdoor Air Required by Code:

Percent Total cfm ______

cfm/Person ______

______

______

2. Air Handling Systems:

	Area				
	1	2	3	4	5
Unit or Systems[1]					
hp Totals					
Supply					
Fan					
Control Method[2]					
cfm (ft^3/Minute)					
Total Supply					
Measured Present					
Outdoor Air (% Total cfm)[3]					
Outdoor Air Leakage Dampers (Closed)					
Hours System "ON"					
Weekdays					
Saturdays					
Sundays					
Holidays					

1 Type (rooftop, multizone, fan coil, central system).

2 No outdoor air, wild economizer, integrated economizer, fixed air.
If economizer is used:
Changeover Control: ☐ Dry Bulb ☐ Enthalpy Set Point ________F.
Mixed Air Control Set Point ________F.

3 Measure 3 temperatures with O.A. Damper in minimum position.

$$\% \text{ Outdoor air} = \frac{T_R - T_M}{T_R - T_O}$$

(T_R = Return Air Temp., T_M = Mixed Air Temp., T_O = Outdoor Air Temp.)

c. HEATING:

Source of Heating Energy:

Hot Water__________ Steam__________ Electric resistance__________

Other __________

Heating Plant:

Boiler No.__________Rating __________ MBH or kW

____

____

Boiler Type:

Firetube__________Watertube__________Elec. resist.__________

Electrode__________ Other__________

Fuel Used __________________ Standby __________________

Hot Water Supply ______________°F, Return ________°F

Steam Pressure__________________psi

Pumps No. __________________ Total hp __________________

Room Heating Units:

Type: Baseboard ________ Convectors ________ Fin Tube ______________

Ceiling or Wall Panels ________ Unit Heaters ________ Other ____________

Extent and condition of metering equipment ____

____

Night Setback: Yes ________ No ________

Morning Warm-up Thermostat Used ____________

d. COOLING:

Type system: ☐ **Packaged rooftop** ☐ **Packaged multizone** ☐ **Central system**

☐ **Chilled water** ☐ **Direct expansion**

Cooling Plant – Compressors and Chillers:

No.	Type (Centrifugal, reciprocating, absorption)	Capacity (Tons)	Motor horsepower	Area Served

Heat dissipation device:

Evaporative condenser ____________

Air cooled condenser ____________

Cooling tower ____________

Chilled water pumps ____________ Total hp ____________ kW

Condenser water pumps ____________ Total hp ____________ kW

Evaporator blowers ____________ cfm ____________ kW input

Condenser fan ____________ kW input ____________

Cooling tower fan ____________ hp ____________ kW input

Cooling night shutdown ____________

Cooling night setup ____________ F

Control System:

Electric ____________

Electronic ____________

Pneumatic ____________

Misc. fans:

Location	Horsepower	Type	Function (Supply, Exhaust, etc.)	Method of Operation (Time Clock; Manual etc.)

SELF CONTAINED UNITS:

Type: Room airconditioner_______ Thru-the-wall unit ______________________________

No. of Units_______ Basic module served ______________________________

Total Capacity (Tons)______________________________

Horse Power/unit ______________________________

Extent and condition of metering equipment ______________________________

Equipment condition and maintenance ______________________________

ENERGY CONSERVATION DEVICES:

Type:

Condenser water used for heating ______________________________

Demand Limiters ______________________________

Energy Storage ______________________________

Heat recovery wheels ______________________________

Enthalpy control of supply-return-exhaust damper ______________________________

Recuperators ______________________________

Condensate used for heating domestic hot water ______________________________

Otherr ______________________________

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LIGHTING:

Area Served	Type (Fuorescent, Incandescent etc.)	Density (Watts/Ft.^{2})	Method of Control (breaker panel, wall switches, control switching)
Interior			
Adm. Off.			
Storage Rm			
Corridors			
Lobbies			
Computer Rm			
Kitchens			
Toilets, etc.			

Exterior

	Type	Total kW
Parking lot		
Decoration		

Equipment condition and maintenance schedules

DOMESTIC HOT WATER:

Size ______________________ Rated input ______________________

Energy Source: Gas ______, Oil ______, Electric ______, Other ______________________

Aquastat setting ______°F

General:

Types of usage – Location of usage, estimated GPD, distance from heater. ______________________

Water temperature – check several locations (reduced temperature during nonoccupancy? ______________________

Type and condition of heat exchange equipment. ______________________

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DISTRIBUTION SYSTEMS:

Condition of Steam Systems (leakage, insulation, etc.)

Condition of Hot and Chilled Water systems (leakage, insulation, etc.)

Condition of Refrigerant Piping (leakage, insulation, etc.)

Condition of Air Distribution Systems (leakage, insulation, etc.)

OTHER EQUIPMENT (Elevators, Escalators, Data Processing, Kitchen, Laundry, etc.)

Equip. Description	Quantity	Size/Capacity in Btu, kW, hp, etc.

OPERATING SCHEDULE

Equip. Description	Unit or Area Served	Weekdays	Saturdays	Sundays or Holidays
Refrigeration cycle mach.				
Fans – Supply, return exhaust, etc.				

HVAC auxiliary equip.	**Unit or Area Served**	Weekdays	Saturdays	Sundays or Holidays
Lighting – Interior				

Lighting – Exterior	Unit or Area Served	Weekdays	Saturdays	Sundays or Holidays

Domestic hot water heat ______________________________

Elevators

Escalators

Other (describe)

DEPARTMENTAL DATA

FOOD PROCESSING – KITCHENS:

Insulation of inbuilt refrigerators. Door locations and seals.

Anti-cycling controls on compressors?

Shutdown of steam/electric equipment when not in use?

Exhaust arrangement – hoods, air quantities, velocities?

Use and condition of hot/cold food carts.

Excessive food serving counters for number of meals served?

Variations in number of meals/day.

LAUNDRY EQUIPMENT:

Age and condition of major equipment

Maintenance procedures

Evidences of condensate loss

Equipment loading practices

Hours of equipment operation

APPENDIX B

SOURCES OF INFORMATION ON ENERGY MANAGEMENT

Here follows a list of sources from whom further information on energy management may be obtained.

1. Societies, Associations, & Institutes

- Air-Conditioning and Refrigeration Institute, 1815 N. Ft. Myer Dr., Arlington, VA 22209
- Air Cooling Institute, P.O. Box 2121, Wichita Falls, TX 76301
- Air Diffusion Council, 435 N. Michigan Ave., Chicago, IL 60611
- Air Distribution Institute, 221 N. LaSalle St., Chicago, IL 60601
- Air Moving and Conditioning Association, 30 W. University Dr., Arlington Heights, IL 60004
- American Boiler Manufacturers Association, 1500 Wilson Blvd., Suite 317, Arlington, VA 22209
- American Consulting Engineers Council, 1155 15th St., N.W., Rm. 713, Washington, DC 20005
- American Gas Association, 1515 Wilson Blvd., Arlington, VA 22209
- American Industrial Hygiene Association, 210 Haddon Ave., Westmont, NJ 08108
- American Institute of Architects, 1735 New York Ave., N.W., Washington, DC 20006
- American Institute of Consulting Engineers (See American Consulting Engineers Council)
- American Institute of Plant Engineers, 1021 Delta Ave., Cincinnati, OH 45208
- American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018
- American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc., 345 E. 47th St., New York, NY 10017
- American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017
- American Society of Plumbing Engineers, 16161 Ventura Blvd., Suite 105, Encino, CA 91316
- American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103
- Associated Air Balance Council, 2146 Sunset Blvd., Los Angeles, CA 90026
- Associated General Contractors of America, 1957 E. St., N.W., Washington, DC 20006
- Better Heating-Cooling Council, 35 Russo Pl., Berkeley Heights, NJ 07922
- BRAB Building Research Institute, 2101 Constitution Ave., Washington, DC 20418
- Building Owners & Managers Association International, 1221 Massachusetts Ave., N.W., Washington, D.C.
- Building Research Advisory Board, National Research Council, National Academy of Sciences-National Academy of Engineering, 2101 Constitution Ave., N.W., Washington, D.C. 20418
- Construction Specifications Institute, 1150 Seventeenth St., N.W., Suite 300, Washington DC 20036
- Conveyor Equipment Manufacturers, 1000 Vermont Ave., N.W., Washington, DC 20005
- Cooling Tower Institute, 3003 Yale St., Houston, TX 77018
- Edison Electric Institute, 1111 19th Street, N.W. Washington, D.C. 20036
- Electrical Apparatus Service Association, Inc., 7710 Carondelet Ave., St. Louis, MO 63105
- Heat Exchange Institute, 122 E. 42nd St., New York, NY 10017
- Hydronics Institute, 35 Russo Pl., Berkely Heights, NJ 07922
- Illuminating Engineering Society, 345 E. 47th St., New York, NY 10017
- Institute of Electrical & Electronics Engineers, Inc., 345 E. 47th St., New York, NY 10017
- Instrument Society of America, Stanwix St., Pittsburgh, PA 15222
- International District—Heating Association, 5940 Baum Sq., Pittsburgh, PA 15026
- Mechanical Contractors Association of America, Inc., 5530 Wisconsin Ave., Suite 750, Washington, DC 20015
- National Association of Oil Heating Service Manager, Inc., 60 E. 42nd St., New York, NY 10017
- National Association of Plumbing, Heating & Cooling Contractors, 1016 20th St., N.E., Washington, DC 20036
- National Association of Power Engineers, Inc., 176 W. Adams St., Suite 1411, Chicago, IL 60603
- National Association of Refrigerated Warehouses, 1210 Tower Bldg., 1401 K St., N.W., Washington, DC 20005
- National Coal Association, Coal Bldg., 1130 17th St., N.W., Washington, DC 20036
- National Electrical Contractors Association, 7315 Wisconsin Ave., Washington, DC 20014
- National Electrical Manufacturers Association, 2101 L Street, N.W., Washington, D.C. 20037
- National Environmental Systems Contractors Association, 221 N. LaSalle St., Chicago, IL 60601
- National Insulation Contractors Association, 8630 Fenton St., Suite 506, Silver Spring, MD 20910
- National LP-Gas Association, 79 W. Monroe St., Chicago, IL 60603
- National Mineral Wool Insulation Association, Inc., 211 E. 51st St., New York, NY 10022
- National Oil Fuel Institute, Inc., 60 E. 42nd St., New York, NY 10017
- National Society of Professional Engineers, 2020 K St., N.W., Washington, DC 20006
- Producers' Council, Inc., 1717 Massachusetts Ave., Washington, DC 20036
- Refrigeration Service Enginners Society, 2720 Des Plaines Ave., Des Plaines, IL 60018

- **Society of American Value Engineers (SAVE), 2550 Hargrave Dr., Smyrna, GA 30080**
- **Standards Engineers Society, P.O. Box 7507, Philadelphia, PA 1910**
- **Steam Heating Equipment Manufacturers Assoc., c/o Samuel J. Reid, Barnes & Jones, Inc., P.O. Box 207, Newtonville, MA 02160**
- **The Electrification Council, 1111 19th Street, N.W. Washington, D.C. 20036**
- **Thermal Insulation Manufacturers Association, Inc., 7 Kirby Plaza, Mt. Kisco, NY 10549**
- **Underwriters' Laboratories, Inc., 333 Pfingsten Rd., Northbrook, IL 60062**
- **Water Conditioning Foundation, 1780 Maple St., P.O. Box 194, Northfield, IL 60093**

2. Local Sources

- **Chapters of above mentioned societies, associations and institutions**
- Utilities
- Chambers of Commerce
- Construction industry organizations
- Building code authorities
- Libraries
- Architectural engineers, contractors, suppliers and others with whom you work on a regular basis.

3. U.S. Government Sources

- Department of Energy, Assistant Secretary for Conservation and Solar Applications, 20 Massachusetts Avenue, N.W., Washington, D.C. 20001
- Department of Commerce, Office of Energy Programs, 14th & Constitution Ave., Washington, D.C. 20230
- General Services Administration, Public Building Service, 18th & F St., N.W., Washington, D.C. 20405
- National Bureau of Standards, Office of Energy Conservation, Building 226, Rm. B114, Washington, D.C. 20234

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2. Federal Power Commission, "A Technical Basis for Energy Conservation," Office of the Chief Engineer, April 1974
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GLOSSARY

Absorption Chiller: A refrigeration machine using heat as the power input to generate chilled water.

Activated Carbon: A form of carbon capable of absorbing odors, anesthetics and vapors.

Ballast: A device used in starting circuit for fluorescent and high intensity discharge lamps.

Blow Down: The discharge of water from a boiler or cooling tower sump that contains a high proportion of total dissolved solids.

British Termal Unit (Btu): A heat unit equal to the amount of heat required to raise one pound of water one degree farenheit.

Building Envelope: All external surfaces which are subject to climatic impact; for example, walls, windows, roof, floor, etc.

Chillers (Centrifugal): A refrigeration machine using mechanical energy input to drive a centrifugal compressor to generate chilled water.

Coefficient of Performance: The ratio of the rate of heat removal to the rate of energy input, in consistent units, for a complete refrigerating plant, under designated operating conditions.

Coefficient of Utilization: Ratio of lumens on the work plane to total lumens emitted by the lamps.

Condensate: Water obtained by changing the state of water vapor (i.e. steam or moisture in air) from a gas to a liquid usually by cooling.

Condenser: A heat exchanger which removes heat from a vapor changing it to its liquid state. (In refrigeration systems the component which rejects heat.)

Control: Any device for regulation of a system or component, manual or automatic.

Cooling Tower: A device that cools water directly by evaporation.

Damper: A device used to vary the volume of air passing through an air outlet, inlet or duct.

Degree Dry: The difference between 65°F and the outdoor mean daily temperature.

Double Bundle Condenser: Condenser (usually in refrigeration machine) that contains two separate tube bundles allowing the option of either rejecting heat to the cooling tower or to another building system requiring heat input.

Dry Bulb Temperature: The measure of the sensible temperature of air.

Economizer Cycle: A method of operating a ventilation system to reduce refrigeration load. Whenever the outdoor air conditions are more favorable (lower heat content) than return air conditions, outdoor air quantity is increased.

Efficacy of Fixtures; Ratio of usable light to energy input for a lighting fixture or system (lumens/watt).

Energy Utilization Index (EUI): A reference which expresses the total energy (fossil fuel and electricity) used by a building in a given period (month, year) in terms of Btus/gross conditioned square feet.

Enthalphy: For the purpose of air conditioning enthalpy is the total heat content of air and is expressed in units of Btu/lb. It is the sum of sensible and latent heat and ignores internal energy changes due to pressure change.

Evaporator: A heat exchanger which adds heat to a liquid changing it to a gaseous state. (In a refrigeration system it is the component which absorbs heat).

Foot-candle: Illumination at a distance of one foot from a standard candle.

Heat Gain: As applied to HVAC calculations, it is that amount of heat gained by a space from all sources, including people, lights, machines, sunshine, etc. The total heat gain represents the amount of heat that must be removed from a space to maintain indoor comfort conditions.

Heat Loss: The sum cooling effect of the building structure when the outdoor temperature is lower than the desired indoor temperature. It represents the amount of heat that must be provided to a space to maintain indoor comfort conditions.

Heat, Latent: The quantity of heat required to effect a change in state.

Heat, Sensible: Heat that results in a temperature change but no change in state.

Heat Pump: A refrigeration machine possessing the capability of reversing the flow so that its output can be either heating or cooling. When used for heating, it extracts heat from a low temperature source to the point where it can be used.

Humidity, Relative: A measurement indicating moisture content of air.

Infiltration: The process by which outdoor air leaks into a building by natural forces through cracks around doors and windows, etc.

Life Cycle Cost: The cost of the equipment over its entire life including operating and maintenance costs.

Load Profile: Time distribution of building heating, cooling, and electrical load.

Lumen: Unit of luminous flux.

Luminaire: Light fixture designed to produce a specific effect.

Make-up: Water supplied to a system to replace that lost by blow down, leakage, evaporation, etc.

Modular: System arrangement whereby the demand for energy (heating, cooling) is met by a series of units sized to meet a portion of the load.

Orifice Plate: Device inserted in a pipe or duct which causes a pressure drop across it. Depending on orifice size it can be used to restrict flow or form part of a measuring device.

Orsat Apparatus: A device for measuring the combustion components of boiler or furnace flue gases.

Piggyback Operation: Arrangement of chilled water generation equipment whereby exhaust steam from a steam turbine driven centrifugal chiller is used as the heat source for an absorption chiller.

Power Factor: Relationship between KVA and KW. When the power factor is unity, KVA equals KW.

R-Value: The resistance to heat flow expressed in units of Sq. Ft. hour Degree F/Btu.

Software: Term used in relation to computers normally describing computer programs and other intangibles.

Ton of Refrigeration: A means of expressing cooling capacity — 1 ton — 12,000 Btu/hour cooling.

'U' Value: A coefficient expressing the thermal conductance of a composite structure in Btu's per square foot hour degree F temperature difference.

Veiling Reflection: Reflection of light from a task, or work surface, into the viewer's eyes.

Vapor Barrier: A moisture impervious layer designed to prevent moisture migration.

Wet Bulb Temperature: The lowest temperature attainable by evaporating water in the air without the addition or subtraction of energy.

ABBREVIATIONS

ASHRAE	American Society of Heating, Refrigeration and Air-Conditioning Engineers
Btu	British thermal unit
Btuh	British thermal units per hour
CFM	Cubic feet per minute
COP	Coefficient of performance
CU	Coefficient of utilization
DB	Dry bulb temperature
ECO	Energy conservation option
EMC	Energy management and control system
G.C. Ft.^{2}	gross conditioned square foot
GPM	Gallons per minute
HID	High intensity discharge (lamps)
HVAC	Heating, ventilating and air conditioning
IES	Illuminating Engineering Society
kVA	Kilovoltampere
kWh	Kilowatt hour
kW	Kilowatt
LCC	Life Cycle Costing
MBh	British thermal unit per hour (thousands)
MBtu	Thousand British thermal units
MCF	Thousand cubic feet
P.F.	Power factor
psi	Pounds per square inch
RH	Relative humidity
TEM	Total Energy Management
WB	Wet bulb temperature

"END OF DOCUMENT"